JOURNAL

OF

THE FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

NOVEMBER, 1864.

CIVIL ENGINEERING.

Steam and Water Pressure Gauges.

From the London Mechanics' Magazine, June, 1864.

A BRIEF review of the different very ingenious and scientific instruments employed for ascertaining fluid pressure may be useful, and the examination will certainly not be without interest. Some of these instruments are based upon very philosophical principles, and it will be worth while to see how these principles withstand the rough contact of daily practice. Steam gauges are now looked upon by no means as "luxuries," though they have been so termed by an eminent writer on the locomotive. Their necessity is recognised, not merely as measures of the safety of the boiler, but also as affording a finger-post to the fireman, who at once knows by the indicator the state of the steam. Partly for this reason, one or two fitters are employed on some of the French lines all round the year solely to travel up and down and keep the steam gauges in order. It is true that a practised touch at the much less delicate safety valve lever will perform a somewhat similar service, but no engineer need be told that a weighted lever is a very rough measure of fluid pressure. And the observation applies to the water pressure of a hydraulic press as well as to steam or air pressure.

Pressure gauges may be divided into four distinct kinds, according to the leading constructive principle adopted :—1. The mercurial pressure gauge—upon the principle of hydrostatic pressure ; 2. The

air manometer, in which the principles of both hydrostatic and pneumatic pressures are combined; 3. Gauges in which the pressure of steam is deducted from its temperature; 4. Metallic gauges, in which the elasticity of metal is used as a measure of fluid pressure. This last kind of gauge may be said to have almost entirely superseded the others for most purposes, on account of the very little attention they require, and from other advantages.

The mercurial pressure gauge consists of a U-shaped tube like a syphon barometer. Its lower part contains mercury; to its legs is attached a divided scale, and one leg communicates with the vessel containing the fluid while the other is open to the air. The difference of the two levels thus shows the difference between the pressure of the steam or water, and the pressure of the external air. When an iron tube is used, the level of the mercury has to be shown by a steam peg or float on its surface. The water stand-pipe, used in the old low-pressure engines to feed the water in by hydrostatic pressure may be said to have been a water-pressure gauge. In both cases, an undue excess of pressure led to either the water or the mercury being blown out of the pipe,—rather an expensive kind of safety-valve, in the matter of quicksilver. The common mercurial pressure gauge may be said to be the only gauge which *per se*, ocularly demonstrates its own exactitude. As, however, the column of mercury would require to be some twenty-eight inches high in order to balance the fifteen pounds pressure of the atmosphere, or fifteen pounds pressure of steam, or a head of about thirty feet of water, it is needless to say that such a gauge is inapplicable to a high pressure boiler. Common gauges should, however, be graduated from a standard gauge of this kind. The use of a small safety-valve for the purpose shows great ignorance. To graduate them from a metallic test gauge of course saves much trouble to the maker, but the plan is scarcely as much in the interest of the buyer. Some fifteen or twenty years ago, a complicated variety of this gauge was in use in France, under the name of the *Manomètre à air libre de Richard.* It is fully described in one of the numbers of our contemporary, the "Annales des Mines," for 1845. It consisted of a syphon with several branches, in communication one with another, filled with mercury in the lower part, and with water in the top portions, in such wise that the differences of level of the mercury in the tubes were added to each other. The same French periodical for 1847 contains a description of an ingenious instrument invented by M. Gazy Cazalat. The steam acts on a piston of a certain diameter, the mercury on a larger piston, and the pistons are kept tight by membranes of vulcanized india-rubber. By properly proportioning the relative surfaces of the two pistons, the column of mercury in the open tube may be made as short as one likes. Neither of these ingenious instruments is now in use, having been superseded by the metallic gauge.

The same fate may be said to have attended the air manometer, although an improved form of this instrument has been lately brought forward by Mr. Allan, of Perth, the inventor of the straight link motion. The common air manometer is a long vertical glass tube, closed at the top end, which contains air. The mercury in the bottom part

soon gets oxidized, and discolors the glass, so that the level cannot be read. The refraction of the glass also distorts the scale. A slight rise of temperature of the compressed air would also greatly affect the indications. As a consequence of Mariotte's law of the compression of gases, the higher pressures are more difficult to read off in a tube of equal diameter throughout. This objection has been obviated by Mr. Allan and others by means of tapering the tube towards the top, but it does not appear that the other defects have been met at the same time. Steam pressure gauges of this kind are forbidden by law under most of the continental governments.

Thermomanometers, or steam gauges indicating the pressure of steam by means of its temperature, generally consist of a large thermometer graduated to atmospheres. Callardeau's thermomanometer (1829) was of this kind. The fragility of the instrument, and its want of sensibility and slowness of indication, have caused it to be abandoned. We remember to have seen an instrument of this kind in use on a boiler in Mr. W. Fairbairn's works at Manchester, some years ago. Thermometers have been made on the well-known compensating principle used in chronometers and compensation pendulums. Two bent strips of copper and steel were riveted or soldered together, and the unequal expansion by heat of the two metals caused a movement which was registered by a wheel and quadrant in the usual way. We do not know whether steam gauges have been attempted on this plan—but the galvanic corrosion consequent on the contact of the two metals in the presence of moisture would porbably soon alter the instrument.

Under the broad heading of metallic gauges comes a great variety of instruments for measuring fluid pressure by means of the graduated motion of a metallic spring. Mr. D. Gooch's steam gauge may be placed under this classification. It consists of a piston working in a cylinder against a spiral spring—in fact, very much like an ordinary MacNaught indicator without the drum. They have not come into use mainly on account of the incrustation of the boiler clogging the piston. Similar instruments were used on French locomotives nearly twenty years ago. The cylinder was kept pretty clear by being separated from the boiler by means of a tap. But it is plain that the intermittent indications thus afforded were not much more than those to be obtained from the safety-valve lever. Messrs. Easton and Amos, the hydraulic engineers, use a gauge upon this principle on a hydraulic press at their works, but they do not trust to it very much. Messrs. Smith's (of Nottingham) gauges may also come under this category. A volute spring takes the pressure through the intermedium of an india-rubber disk stretched across the tube. Messrs. Salter & Co. also use an india-rubber disk in this way, which performs the same function as in Gazy Cazalat's old gauge. Amongst other objections these gauges are liable to injury in course of time, through the induration of the india-rubber, caused by its partial corbonization. The cheapness of the plan has led to several others of its form; but it is one thing to make a gauge that will be accurate at first, and it is another thing to make one that will keep right for a length of time.

A German writer has neatly classified the different principles of purely metallic gauges under the following heads:—1. Every hollow ball, subjected internally to the pressure of a fluid, will keep its spherical shape. 2. Every hollow elastic vessel, subjected internally to the pressure of a fluid has a tendency to assume the spherical shape. 3. Every hollow cylindrical tube, subjected internally to the pressure of any fluid will strive to keep its cylindrical shape. 4. Every straight tube, the cross-section of which is not circular, and which is subjected laterally to fluid pressure, has the tendency to assume the cylindrical shape. 5. Every hollow bent tube, the cross-section of which is a circle, and which is subjected internally to fluid pressure, will keep its shape. 6. Any bent tube, the section of which is elliptical, and which is subjected internally to fluid pressure, will have the tendency to straighten itself, if the longer axis of the ellipse is at right angles with the plane of curvature of the tube, that is to say, the extremities will have a tendency to increase the distance between each other. The contrary will be the case if the longer axis of the ellipse coincides with the plane of curvature of the tube, and the tube will then have a tendency to curve itself still more—to bring its extremities nearer to each other. Schaeffer's, De Witt's, and the numerous gauges formed out of a number of superposed hemispheres, come under principle No. 2. Schaeffer and Budenberg's gauges are fitted with a corrugated circular steel plate to receive the steam pressure. The plate is coated with silver on the steam side. This is intended to prevent corrosion; but we have sometimes noticed a certain amount of galvanic corrosion from the contact of the two metals. The corrugations are concentric, being similar to the concentric ripples caused on the surface of water through the vertical fall of a stone. The back of the pointer is fitted with a spiral spring, in order to absorb any looseness of the working parts. De Witt's gauges consist of a hollow chamber formed of two disks, each consisting of three or four thin steel plates. The chamber is collapsed by the pressure, and thus affords a longer range than the single disk of Schaeffer. A similar gauge to Schaeffer's was patented in England in 1844 under the name of Fontainemoreau. Cuny, in Germany, made some years ago gauges in which the motion of a metallic plate was taken off by a column of mercury, the rise and fall of which in a tube indicated the variations of pressure. This plan is simple, but the results are liable to be affected by temperature, and other causes. Gauges made of a number of flattened spheres appear difficult to keep from leakage, and no gauge of this kind seems to be commonly used. Under principle No. 6 come Bourdon's admirable gauges patented in France and in England in 1849. The greatest breadth of the tube is generally placed in the direction perpendicular to the plane in which the tube is curved, and the tube then becomes more curved or less curved, respectively, according as the pressure within, is greater than without, or the pressure without is greater than the pressure within. Although the Bourdon gauge has been accused of taking a permanent set, and also of taking what may be termed a temporary set—that is, not coming back at once when the pressure is withdrawn—our own

experience leads us to prefer these gauges to any other. The American makers of the Bourdon gauge, Messrs. Ashcroft, of Boston, patented several years ago a form of Bourdon gauge made with two springs or tubes one inside the other. Messrs. Dewrance, in the Borough, have patented a similar plan in England, but they use three brass tubes—drawn by Muntz's process—one within the other. This plan is stated to afford more elasticity within a smaller compass. Messrs. Bailey, Blake, and Bailey, of Manchester, have also lately patented what they probably call an improvement on the Bourdon gauge. The tubes are constructed either in two portions, one side of brass and the other of steel, or by "fixing a steel band against one side of a brass tube." There is no doubt that "by this means they obtain a greater deviation of shape in the tubes when subjected to pressure or acted upon by heat;" but we are inclined to predict that galvanic corrosion will make quick work of the steel half, and thus affect the indications.

As a commentary on the above we may mention that Mr. Amos, C.E., the Consulting Engineer of the Royal Agricultural Society, makes it a practice to test all the steam gauges of the boilers that are intended to work at the Shows. They are all tried in a parallel row on a steam pipe, to which is affixed the standard gauge. We have thus seen almost every one of these gauges give a different indication. Such store does the French government lay on good steam gauges and their proper state, that it is specially decreed that every boiler in France should be fitted with a pipe and flange, to which a test gauge can be at once attached by the government inspector. The obvious deduction from these facts is, that the greatest care and attention should be used in the selection, repair, and watching of the steam gauge. The employer of steam power will then find his reward, not merely in the increased safety of his boiler, but also in the saving of fuel.

Atmospheric Railways.

From the London Mechanics' Magazine, September, 1864.

Exactly fifty-four years ago, a Mr. Medhurst proposed that a brick tunnel should be built and applied to the conveyance of passengers, at speeds never more than dreamt of before. Within the brick tunnel a pair of rails were to be laid, and on these rails a suitable vehicle, very similar in its general arrangements to an ordinary railway carriage, was to travel. The cross section of the brick tube, as proposed, would have been egg-shaped, with the maximum width above. The rails would have rested on projections springing from the side walls near the bottom. To the rear of the carriage, a piston, so to speak, formed of boards suitably framed together, would have been affixed. This piston would have nearly fitted the tunnel. Whether any expedients were proposed by which the space between its edges and the brick-work could be made partially air-tight, we are not prepared to say. It is not likely that a scheme so perfect in principle as this was, would be found wanting in detail. The carriage and piston thus

provided, and put in place within the tube, air was to be forced in behind by means of a large pumping apparatus, very similar, we believe, in general design, to the blowing engines at present used at our iron-works. The pressure of the air thus pumped in, would, it was contended, prove sufficient to propel the carriage with its load of passengers at very high speeds. Mr. Medhurst lived before his time. The scheme never got beyond a model for obvious reasons. In the first place, the steam engine was not yet perfected, and the obtention of the necessary motive power for the blowing machinery was by no means easy. In the second place, people had a very great and perhaps natural antipathy to the idea of being placed within a tube, dark and cheerless, and blown to their destination; and thus a really valuable invention fell to the ground. It is easy, however, to see that Medhurst's was no ordinary mind. In this scheme we have the embodiment of nearly all that constitutes the modern railway—the iron rails, the high speeds, the accommodation for passengers, have a great deal in common with the present system of locomotion, and all this, be it observed, was designed twenty years before the Rainhill trials inaugurated the railway system. After Medhurst came Vallance and Pinkus, gentlemen who proposed certain alterations, the principal idea being involved in the reduction of the size of the tube; the alteration of its position with regard to the carriage, by placing it between the rails and below the floor; and the exhaustion of the air from the space in front of the piston, instead of its compression within the space behind; but this last had been already proposed by Medhurst, who seems to have left scarcely a point overlooked. Messrs. Vallance & Pinkus had no better success than Medhurst, and it remained for Messrs. Clegg & Samuda, years afterwards, to develope the system on a practical scale on the London and Croydon, and Dalkey and Kingstown railways. The atmospheric principle as tried on these lines is now well known to be wholly unsuitable to the demands of an extensive traffic, and, as far as the country is concerned, the vacuum tube and the piston carriage have been banished for ever in favor of the locomotive. With the introduction, however, of the underground metropolitan railway system, the old scheme of Medhurst bids fair to be revived. Indeed, there is hardly room to doubt that it is, of all others, the most suitable for the exigencies of this species of traffic. In the pneumatic dispatch we have, on a small scale, all that Medhurst proposed; and there can be no room to doubt, from the success which has already attended upon the labors of the company, known by the same name, that the system can be extended to the conveyance of passengers without any practical difficulty whatever. During the last few months, too, Mr. Rammel, the inventor of the pneumatic dispatch scheme, has been laboring at the Crystal Palace to provide a model line—the first on which regular passengers have been conveyed—which would serve to bring all these advantages fairly before the public.

The tube extends from the Sydenham entrance, to the armory near Penge-gate—a distance of about a quarter of a mile, and it is, in fact,

a simple brick tunnel, nine feet high, and eight feet wide—a size that renders it capable of containing an ordinary Great Western Railway carriage. That actually working in the tube at this moment is handsome and commodious. The piston is rendered partially air-tight by the use of a fringe of bristles extending nearly to the brick-work of the tunnel and its floor. A fan 20 feet in diameter is employed to exhaust or to force in air, and perhaps it is impossible to devise any other expedient so well calculated to answer the required purpose. It must be remembered that either a plenum or a vacuum equivalent to ·5 of an inch of mercury is quite sufficient to propel even a heavy train at a high speed on a moderately level line. In the present instance the motive power is supplied by an old locomotive borrowed from one of the railway companies, which is temporarily mounted on brick-work. The tires have been removed from the driving wheels, and these last put the fan in motion by straps.

The line, we have said, is a quarter of a mile long; a very small portion of it, if any, is level, but it has in it a gradient of one in fifteen—an incline which no engineer would construct on an ordinary railway; and as it is not a level line, so it is not a straight one; for it has curves of only eight chains radius, which are shorter than those usually found in existing railways. The entire distance, 600 yards, is traversed in about 50 seconds, with an atmospheric pressure of but $2\frac{1}{2}$ ozs. The motion is of course easy and pleasant, and the ventilation ample, without being in any way excessive. All the mechanical arrengements are so simple and must be so obvious we imagine, that it is needless to dwell on them. We feel tolerably certain that the day is not very distant when metropolitan railway traffic can be conducted on this principle with so much success, as far as popular liking goes, that the locomotive will be unknown on underground lines.

Krupp's Steel Tires.

From the London Mechanics' Magazine, September, 1864.

Messrs. Prosser & Son, the American representatives of the Essen firm, publish a circular containing some interesting facts, of which we select a few. Thus we learn that there are manufactured at Krupp's per day some one hundred tires, of which number one-half are for Great Britain alone. The magnitude of the tire manufacture can be estimated by the fact that forty steam hammers are employed on tires alone at this establishment. Messrs. Prosser & Son state that they have in their possession a turning, taken from a Krupp tire at the Erie Railway shops at Dunkirk, U.S., which measures 727 feet, showing the extraordinary toughness and homogeneousness of the metal.

The circular gives some interesting facts regarding the wear of the tire in America. On the Chicago, Burlington, and Quincy Railway, a goods engine weighing 34 tons ran 29,500 miles, and the wear was only 3-32d of an inch, and the tires are considered good for another year before coming to their first turning; on the Ohio and Mississippi

Railway, a set of these tires on a 32-ton engine ran 60,485 miles with a wear of $\frac{5}{16}$ths of an inch; on the Erie Railway a set of these tires, on a freight engine with four driving wheels having a crushing weight of 6½ tons on each wheel, ran 21,450 miles, with a wear of less than $\frac{1}{16}$th of an inch, and Assistant Superintendent Brooks expresses the opinion that they will run 100,000 miles before coming to their first turning. Several other instances are mentioned of the great wear of the tire in this country. Mr. Prosser remarks: "That there is a great fallacy in comparing the wear of iron with Krupp's cast steel tires on the first turning; for, when an iron tire requires turning the first time, it is usually half worn out, and sometimes even more than that: whereas, Krupp's wear equally well from first to last, however many times they have been turned. This is in consequence of the great resilience of the *peculiar* metal which does not suffer the slightest disintegration under the heaviest load."

Since 1854—55, Mr. Krupp has furnished the Bavarian State Railway with,—

740 tires for driving wheels.
640 tires for tender wheels.
664 tires for trailing wheels.
1766 tires for carriage wheels.

The General Director of this road says:—"The durability and security of the Krupp tire has proved so economical that we have determined to use none other. Of the driving wheel tires, 664 were put in service in 1854; and of these, only 29 had been worn out. Of the carriage wheel tires put in service in 1857—58, not one has worn out or proved defective up to the present time," June, 1862.

A set of Belgian (D'Acier Lamine, puddled or semi-steel) tire, ran but 18,640 kilometres, (11,582 miles,) with a wear of a shade over one-eight of an inch.

With the same wear, a set of Krupp's tires ran 65,774 kilometres, (40,871 miles.)

This comparative test was made on the Luxembourg Railway.

It would appear, from this and other data, that for each quarter of an inch worn these tires will run on good roads some 80,000 miles. 2¼ in. tires will usually bear turning three times, wearing as well at last as at first. Their total life or mileage may therefore be stated at 300,000 to 400,000 miles, according to character of service performed.

On the Power required to overcome the Vis Inertiæ of Railway Trains.

From the London Mechanics' Magazine, September, 1864.

Mr. Peter W. Barlow read a paper "On the Power required to overcome the Vis Inertiæ of Railway Trains, with description of machine to propel trains between stations without locomotives," and the following is an abstract:—It was reported to the inventor, who was engineer of the South Western Railway for many years, that when the North Kent Railway was opened to the public, a great consumption of coke arose. He examined into the cause, and found by

a series of experiments made on locomotives, and on the atmospheric railway, that the loss arose from the power required to overcome the vis inertiæ of the train. It then became necessary to have locomotives of greater tractive power and weight, which had increased until this day, when they were of sufficient power to put a train of 80 tons into a velocity of 18 or 20 miles per hour before the last carriage left the platform. Having observed this, it occurred to the inventor to try using hydraulic power for the length of the platform, that a degree of momentum might be given to the train which would be sufficient to carry it to the next station, on railways where the stations are frequent, and the power of this operated, as was represented by an attractive force of eight tons, acting over a length of 300 feet, as sufficient to put a train of 60 tons into a velocity of 34 miles an hour and which velocity was sufficient to carry a train a mile and quarter on a level from its own vis inertiæ, and therefore half a mile beyond the next station, if the distance were three-quarters of a mile. He estimated that one 30 horse-power stationary engine, by these means, would propel trains every five minutes a distance of one mile at a cost of £1 per day. He explained that the economy of this arrangement arose partly from using stationary power instead of locomotives, and partly for more rapidly overcoming the inertiæ of the train, which he explained by models he laid before the Section. The inventor's estimate of the length the train would run, with a velocity of 34 miles, was proved from experiments made with that object on the Lancashire and Yorkshire Railway by M. Pambour.

Captain Selwyn said that in America a 15-ton engine had done the work, upon an incline, of 30 tons by adhesion. The invention was one of Mr. Armstrong's, who was well known in connexion with telegraphic science in America. He placed a coil of large copper wire around the driving wheel, below the semi-diameter. It was hung there from the frame of the engine, consequently the driving wheels rotate inside it without touching it at any point. A current was sent from a 12 cell battery of 18 inches in height and 4 in diameter, and the electro-magnetism produced in the coil was sufficient to produce the adhesion to the rail. The wheel never skitted while the electro-magnetism was on, and by preventing this skitting additional power was obtained.

Sir W. Armstrong said it was quite obvious that any principle of this kind, which dispensed with the weight of a locomotive and tender, would lessen the amount of locomotive power to produce the run. If successful, and applied to underground railways, the greatest objection was got rid of to those railways. He had no hesitation in saying that it was perfectly practicable to produce power in the way proposed; but whether the system would have to contend with practical objections and difficulties strictly appertaining to the working of railways, that was a point upon which he could not give an authoritative opinion, for it was a matter more for the consideration of gentlemen who were connected with railways to see whether the working of the system was practicable. When a thing was right in principle, it was quite aston-

ishing how practical difficulties melted away in the course of time and experience. It was likely a great many objections would be urged, and he could conceive many himself, but he would not venture to say that something of the sort would not prove to be practicable. He should be glad to hear what gentlemen conversant with the working of railways would have to say on the subject, and he thought the Section ought to entertain it, and give it a fair and careful consideration.

Mr. Fairbairn said that, in obtaining a momentum of 30 or 40 miles an hour in a space of 100 yards, the question arose whether it would not be dangerous and destructive to the comfort of the passengers in the train. He agreed with Sir William Armstrong in the correctness of the principle, and that the time would arrive when it would be accomplished. In the metropolitan railways it would he very desirable to dispense with the steam engine, and whether it was done by the system recommended by Mr. Barlow, or the system of ropes, the same as the Blackwall railway was worked for a number of years, it would be much more comfortable to passengers than the present system of locomotives. The matter deserved a close investigation, and he hoped that something might come of it.

In answer to a question,

Mr. Barlow said brake power would be applied by the guard.

Mr. Vignolles said he thought that after some practice many other difficulties which appeared at present might be overcome. The question was, whether within a distance of 100 or 150 yards a velocity could be obtained of 40 or 50 miles an hour, for in many cases that velocity would have to be obtained to overcome a rise. That appeared to him to be a considerable difficulty independent of others. It was well known on the Blackwall railway that the distance between the last station and the last but one was effected by casting off the train from the rope, and allowing it to arrive at the station by its own velocity. There were a number of difficulties which must be overcome, not only in experiments, but practically, and the system now proposed was, in fact, almost reverting to the stationary system.

Mr. Barlow said he did not think there would be any jerk in the train in getting up the speed within the distance he had referred to.

The President said the paper had re-opened the inquiry into the relative merits of stationary and locomotive power, which was fully discussed 20 years ago, since the period the question was considered to have been set at rest. It was a loss of power to have to transport the motive power along with a train, the dead weight being 45 tons, and, *a priori*, it was an advantage to be without the dead weight of the locomotive tender; yet for certain particular reasons all engineers had for many years arrived at the conclusion that, with all the disadvantages of the system of working by locomotive engines—tested by any system of fixed power that has yet been devised—it was infinitely the best, so that in all cases where fixed power had been provided at vast expense, that power had been removed and locomotives substituted. There was no doubt that railways in some particular localities were assuming a form which rendered it not inadvisable to

re-consider the question, or, in fact, to compel engineers to re-consider it. Rightly or wrongly, the inhabitants of the metropolis were condemned to travel in subterranean ways. For the sake of streets and buildings, and for the sake of avoiding the destruction of property, it seemed to be ordered that the inhabitants of London should not travel in daylight, but underground. It was quite evident that with the growth of the metropolis and increase of traffic in underground railways, the nuisance must become insupportable in consequence of the engines emitting nauseous gases. The question would become one for engineers; and it was therefore we felt much indebted to Mr. Barlow for bringing the subject before the Section. In his opinion, railways were entering on a new phase, and a new motive power could not be arrived at without a great deal of consideration.

Railway Working Expenses.

From the London Artizan, Sept., 1864.

The total working expenses of the railways of England and Wales in 1863 amounted to £ 12,659,618, against £ 12,050,581, in 1862; of the railways of Scotland to £ 1,617,204, against £ 1,520,056, in 1862; and of the railways in Ireland to £ 750,412, against £ 697,772 in 1862. The aggregate of the United Kingdom was thus £15,027,-234 in 1863, against £ 14,268,409 in 1862. The length of the line in operation at the close of 1863 was 12,322 miles, at the close of 1862 11,551 miles. The totals given do not include steamboat, canal, and harbor expenses; and the figures for 1863 are also exclusive of the working charges of the Oswestry and Newtown, Cowes and Newport, Brecon and Merthyr Tydfil Junction, Cork and Kinsale Junction, Dowlais and Hereford Hay, and Brecon. The ratio of expenses to receipts appears to have been reduced last year to 48 per cent., against 49 per cent. in 1862. The working expenses of last year may be analyzed as follows:—Maintenance of way and works, 18·95 per cent., against 18·99 per cent. in 1862; locomotive power, 27·62 per cent., against 27·79 per cent. in 1862; repairs and renewals of carriages and wagons, 9·33 per cent., against 8·71 per cent. in 1862; traffic charges (coaching and merchandise), 27·92 per cent., against 27·95 per cent. in 1862; rates and taxes, 4·20 per cent., against 4·18 per cent. in 1862; Government duty, 2·63 per cent., against 2·63 per cent. in 1862; compensation for personal injury, &c., 1·19 per cent., against 1·11 per cent. in 1862; compensation for damage and loss of goods 0·46 per cent., against 0·48 per cent. in 1862; legal and parliamentary expenses, 1·30 per cent., against 1·54 per cent. in 1862; and miscellaneous, 6·40 per cent., against 6·62 per cent. in 1862.

Railway Accidents.

From the London Artizan, Sept., 1864.

In the year 1861, 79 passengers were killed and 789 injured by railway accidents in the United Kingdom; in the year 1862 on an increased number of lines 35 passengers were killed and 536 injured;

and in the year 1863 on a still increasing length of lines 35 passengers were killed and 401 injured. The number of passengers in 1863 was 204,635,075, without including 64,391 season and periodical ticket-holders. Estimating even that these last traveled on an average only 100 times each, the number of passengers killed in 1863 was less than one in 6,000,000, and of passengers injured less than one in 500,000. Of every five passengers killed, three lost their lives through their own misconduct or want of caution, so that the number of passengers killed from causes beyond their own control was less than one passenger in 15,000,000. Of the passengers killed last year 12 met their deaths by getting out of, or attempting to get into trains when in motion, 5 by incautiously crossing or standing on the line at a station, one by leaning out of the carriage window on approaching a bridge, (since widened), one by getting out on the wrong side of a carriage, one (in Ireland) by getting upon the roof of a carriage and walking along the train. Of the 13 passengers killed in 1863 from accidents to trains, 3 lost there lives through collisions between trains and ten from trains getting off the line, 7 of the 10 in the accident on the Hunstanton line caused by a heifer being on the rails. Of the whole number of accidents to passenger trains in the United Kingdom reported to the Board of Trade in 1863—52 in all, exactly one a week and precisely the same number as was reported to the Board in 1862—32 were caused by collisions with other trains, 10 by the trains getting off the rails, 6 by their running off the proper line through the points being wrong, and only 4 from anything breaking or getting out of order.

Improvements in Metallic Piers and Piles.

From the London Artizan, Sept., 1864.

Mr. J. Phillips has just patented some improvements in piles or cylinders for piers, embankments, coffer-dams, and other structures that are wholly or partially under water. The invention relates to the means of rendering more or less perfectly water-tight the vertical joints, interstices, or spaces existing between the metal piles or cylinders employed for structures that are wholly or partially under water, and consists in forming grooves, recesses, shoulders, or flanges upon the contiguous sides of such piles, and then inserting into such grooves or recesses, or against such shoulders or flanges, pieces of wood or other suitable material, so formed that the pressure of the water causes them to fit tightly against one or more surfaces of the grooves, recesses, shoulders, or flanges of two contiguous piles or cylinders, thereby preventing the water from penetrating through the joints, interstices, or spaces between the two piles to the back of the same. It is preferred to make the grooves in the piles, and the pieces of wood to be inserted therein, of a rectangular form, and to form the lower extremity of the piece of wood with a double incline, so that when driven into the ground it is made of itself to press against the back surface of the two grooves and the side surface of one of them. In some cases

the grooves and pieces, of wood are formed so that when the latter are in their places, wedges or packing pieces may be inserted so as to press the piece of wood against the back surfaces, or back and side surfaces of the grooves independently of the action of the water, or the grooves or pieces of wood may themselves be made of inclined surfaces so as to produce a wedging action. In some cases the pieces of wood are compressed before inserting them into the grooves, so that when they come in contact with the water they swell out, and thus of themselves exert a pressure against the surface of the grooves. India-rubber, felt, or cork, in combination with iron, may be used in place of wood for forming water-tight joints in the said structures.

The Great Explosion of Gunpowder; and the Breach in the River Embankment.

From the London Builder, No. 1131.

Warnings of danger to this metropolis from the storage of large quantities of gunpowder, even at places so distant as Purfleet, Plumstead, or Belvedere, have been occasionally uttered,—though they have not received the same attention as those referring to the accumulation of petroleum and other combustibles, in buildings amongst the streets of London. But the magnitude of the danger has been demonstrated since our last number appeared; and consequences hitherto unapprehended, involving, from the particular explosion, the inundation of a large area of valuable reclaimed land, and that of the extensive low-level inhabited districts in the south or south-east of London itself, besides injury and delay to the sewerage works, have been averted only through a most fortuitous conjuncture of circumstances, the presence of mind and the skill of one or two individuals, and the immediate energy and laborious exertions of a great force of men.

On Saturday morning last, at about twenty minutes before seven o'clock, there occurred at a certain spot on the southern bank of the Thames, near Belvedere, and distant about one mile above the church of Erith, and the same distance below the reservoir and Outfall of the whole main drainage of that side of the river, an explosion of a quantity of gunpowder which appears to have far exceeded in the amount that of any explosion in time of war, whilst the sound and concussion reached to places at a distance of eighty, ninety, or approaching one hundred miles. The quantity is estimated to have been 1040 barrels of 100 lbs each, or in all nearly 46½ tons. It was contained in two magazines, which stood close behind the embankment or river-wall of the Thames, and in two barges outside; but the quantity that was in one of the buildings formed a considerable portion of the whole, and amounted to 750 barrels. The destruction of life, or personal injuries, by the explosion itself, fell almost exclusively upon the few individuals, and their families, who were in charge of the magazines, or on board the barges, or engaged in the work of loading or unloading; and it may not have exceeded about twenty individuals five of whom are dead whilst we write, and five are "missing" or represented by fragments

of heads, arms, feet, or mere pieces of flesh. Individuals not connected with the magazine, nor on board the barges, however, were killed or injured; amongst the killed were two men who were at the time about proceeding to their work in certain repairs to the river-wall at a place adjacent to the scene of the explosion. The destruction of property however, was immense; though it is rather to be realized from the accounts, albeit inadequate, than discovered by a visit to any single spot. Where stood the buildings, there are now scarcely ruins, and the bricks of the magazines strew the ground as so many pieces cleaned of their mortar, better than could have been done by hand. A wide cavity in the earth shows where stood the principle building, a substantial structure, belonging to Messrs. John Hall & Son, of the Faversham Mills, and about 50 feet square. It was erected five or six years ago, at a cost of about 3000*l*. The other magazine, variously stated as about 60 or 70 yards distant, or as about 300 or 400 yards, belonged jointly to the Elterwater and the Lowood Gunpowder Companies, and measured about 40 feet by 30 feet. Each building was in two floors, and had a wooden jetty for the unloading and loading of vessels. The other buildings were three cottages, occupied by the two store-keepers, one of whom is living, and by the work-people, and were at some distance from the magazines. The barges were blown into fragments, which fell into the river, or with some portions of the buildings and their furniture, and of human limbs, were projected to incredible distances. Some of the business papers were carried into Woolwich Arsenal, distant four miles. This latter place was, by the inhabitants of Woolwich, at first thought to be that of the explosion. The embankment wall, for about 300 feet in length, was forced into the river; and the marshes of Erith and Plumstead, and parts of London itself, which the water covered before the period of authentic history, were laid open to the rising tide. The consequences of this portion of the calamity, to which we have alluded, have at present been averted, as we have said; but in their full extent, they are to be estimated only by professional readers, acquainted with the districts in and east of London, and their levels, with the formation of the banks of the Thames, and with the accounts of some previous breaches. Now, the public mind rests impressed chiefly with the recollection of the concussion, and with the facts including those of the injury done in the villages of Belvedere, Erith, and Plumstead, in the town of Woolwich, and in parts of the eastern and southern districts of the metropolis proper. Glass was broken, and window frames were forced in; so that in Belvedere, distant about three quarters of a mile from the magazines, and in other places, houses have been rendered uninhabitable. Ceilings and chimney pieces were broken, and walls were so shaken, that at least one house, and this one at a considerable distance, has since fallen. Even in London, in the Minories and Aldgate, plate glass was broken; whilst at the Crystal Palace a door was burst open; and in Norwood, a house that was in erection has been greatly injured. Such effects as these last were experienced at distances of 10 or 12 miles. Though three distinct shocks are reported to have been felt, the almost instanta-

neous spread of combustion from grain to grain of the powder, barrel to barrel, floor to floor, and building to building, is surprising, even with the knowledge of the properties of gunpowder, and the infinitesimal thread of a train, or leakage, that suffices to establish a connexion between one enveloped quantity and another. The occurrence will doubtless receive attention from men of science; but we may note that one statement refers to the falling down of grains of powder apparently unconsumed.

It is now seriously discussed, whether the storage of large quantities of gunpowder in places distant but one mile, or even ten miles, from a populated district, should be permitted. Half-way between the site of the catastrophe, and that of the Southern Outfall of the sewerage, is another magazine, to which happily no matter in combustion gained excess, though glass was broken. Tiles were blown from roofs of buildings further distant. Close adjoining the property of the Metropolitan Board of Works, is yet another magazine, which was empty, but to which the attention of the Board is, we believe pointedly directed. Further west, or above Crossness Point, is still another magazine, this last belonging to Government.

The chimney and buildings of the Outfall works, received no damage beyond that of the fracture of plate glass of the value of about 150*l*. But had the marshes been inundated, the Outfall sewer itself, with its numerous ventilating shafts, as well as side entrances,—and without considering the existing state of the several channels in connexion with the reservoir,—would have been flooded; and the sewage would have been dammed up, even as far as Battersea. The invert of the sewer at the outfall, is 28 ft. 6 ins. below the high-water level; whilst the surface of the ground where the engine-house and other buildings stand, is itself 6 or 7 feet below the level. A breach in the embankment, beyond the jurisdiction, or works, of the Metropolitan Board, is thus seen to be a serious matter of consideration. Fortunately, on this occasion, there was a body of workmen who were able to proceed at once to the scene of the disaster.

Every circumstance of time and tide, availability of competent direction, presence of men at the works of the Outfall, vicinity of a great and disciplined military force with tools and appliances, and even the soil at the spot, happened to be favorable; and a more serious disaster than has occurred within recollection, by a breach in an embankment of the Thames, was by the greatest exertions staved off, and at length was, as we have said, averted. The manner in which the whole business was conducted, merits record in these pages; and the instance may be instructively compared with the experience of previous accidents as related in various books, where the loss to landowners, and the injury to the navigation of the Thames, through the years duration of breaches and by the repeated failures of attempts to close them, is graphically related.

The great destruction of property, and probably of life, and the loss and delay which we have endeavored to convey an idea of, would have ensued from the breach at Belvedere, but for the circumstances

to which we have alluded, and the course immediately taken. When the explosion occurred, it was the most fortunate circumstance that the tide was low; but there were only about four hours wanting to the time of high-water. The explosion had forced the greater portion of the materials of the embankment, in the 300 ft. of length acted upon, into the river, only throwing up on the foreshore a low mound, not capable of affording any protection. In the 300 ft. gap which was formed, the space which had been occupied by the foundation or base of the embankment wall was filled with broken and shapeless masses of earth or clay, which had formed part either of the consolidated mass of wall, or of the site of the magazines. The few men who were engaged on another portion of the embankment, were, at the moment, the only hands available for work obviously necessary for the exclusion of the rising tide, but which to be finished, not in the most substantial way, in three or four hours time, demanded the labor of many hundred men.

Amongst the residents of Erith, who were all roused by the explosion, was Mr. Lewis G. Moore, an engineer who has been connected with Mr. Furness, in the contrivance of some of the means of executing the work of the Thames Embankment of these present days. Led to the spot, he immediately saw and appreciated the impending calamity, and recognised the necessity of setting to work a much larger force than that of the few men who were at hand. He at once despatched his card, with a huriedly written request, to the resident engineer, of the Main drainage works, or his representative, to bring immediately all the men, with barrows, picks, spades, and other requisite tools, that he could muster.

The explosion had startled every one at Plumstead. Mr. F. R. Houghton, one of the engineering staff of the Metropolitan Board, and representing Mr. Grant and Mr. Bazalgette, is resident there; and he was aroused, and was soon on his way. He was met by Mr. Moore's messenger. The men at the Outfall works seem to have had the idea at once, that their services would be required; and they started, about 400 in number, on the moment that Mr. Houghton gave the order. To both Mr. Moore and Mr. Houghton the highest praise that we could give them would not be too much; and the first of these gentlemen has most deservedly received the thanks of a public meeting at Erith. Whilst Mr. Houghton, with Mr. Webster's navvies were on the way, and immediately upon their arrival, Mr. Moore directed the filling-in of the interstices of the lumps of earth, with puddle, rather as the best extemporized foundation, than as a sufficient substitute for a properly consolidated one. The work was punned in and rammed as well as time would permit; but it became evident almost immediately to Mr. Moore and Mr. Houghton, that the force under them would be insufficient. They then forwarded a communication to Major-general Warde, the commandant at Woolwich; and the result showed that "the system" must have undergone a change calculated to gratify the people of England; for, by half-past nine o'clock, detachments of sappers and artillery, to the number of about 1500, were on the ground,

with appliances of military engineering. They were under the immediate command of Colonel Hawkins, of the engineers; but General Warde was also present. They were followed by the 5th Fusiliers, and the Marines, some of the force being necessary to keep the ground; for, as the day advanced, great crowds were attracted from the surrounding places and from London. A considerable amount of work had been done before the troops arrived; but it was necessarily hurried, as it was essential to keep above the rising tide. The work contended with the tide, to use the words of those who were present, "inch by inch;" but it was kept always above the tide.

The troops brought with them a few thousand bags, such as, filled with sand, are used in the construction of sand-bag batteries; these were filled with clay, which was fortunately to be had by digging; and the bags were passed from hand to hand, and laid in the form of an arch or plan, to make the landward-side of the upper half of the embankment, puddle being filled in between them, and the whole being rammed down, now in a more complete manner than had been possible at first. At length, about two or three o'clock, the work was completed, having withstood the tide. In the night of Saturday, it sank, as had been expected, 6 or 8 ft., and water trickled through. The military and navvies were actively occupied, backing up and ramming the work, on Sunday, when the embankment was exposed to the waves washed by a heavy gale, and stood the test. Next day, we believe, it passed into the hands of the Dartford Commissioners, when a band of navvies were engaged, still further consolidating; and the work was reported as secure as the original wall. On Wednesday, however, there were still 200 navvies engaged; and it had been deemed prudent to fill up the hole in the foreshore, caused by the explosion of the barges, with chalk stone, of which 100 tons were thrown in. At one time, on the Saturday, the danger seemed so imminent, that Mr. Moore proposed, if he did not actually make arrangements for, the scuttling and sinking of a dozen barges loaded with clay, to form a breakwater in front of the breach; but this arrangement, if Perry's reasoning on his experience at Dagenham be correct, could have been only a forlorn hope; as there would have been scour under the bottom of the barges; and, in two or three tides, a deep channel might have been scooped out.

The manner in which the military went to their work, elicited the admiration of all who saw it, including that of the navvies; and the civil engineers named, have expressed their warm acknowledgments. It is evident that without the force and dicipline of the great body of men brought upon the ground on Saturday, and again on Sunday, the previous labor (not bating a particle of the credit due for it) would have failed to cope with the difficulty.

How the matter of accounts with Mr. Webster, is to be settled, we have not heard; but there seems some doubt whether actions will lie against the proprietors of the magazines, by any of the parties who have suffered, or whether the insurance offices can be expected to treat the injuries to property insured only against fire as having resulted

therefrom; though one or two offices are understood to be ready so to consider the injuries.

We have hinted that there is some reason to apprehend that the embankments of the Thames, which are said to make in the total 300 miles, are not as they should be for security. The danger averted,—and, as we have shown, through a most fortuitous conjuncture of circumstances,—will, we hope, incite the several Commissioners, and the Conservators of the Thames, to consider whether better survey, and more frequent reparation of the embankments and sluices are desirable; and whether it would not be well to prevent such risk as is proved to be incurred by the storage of gunpowder in a position where explosion may cause a breach.

For the Journal of the Franklin Institute.

General Problem of Trussed Girders. By De Volson Wood, Prof. of C. E., University of Michigan.

(Continued from page 236.)

If the diagonal bars act as ties, and $b\ c$, Fig. 5 is subjected to a strain, we will make a section just at the left of b. We might use the former section and take the origin at c; or we might let the origin remain at a, but in the latter case we would have two moments, one the moment of $b\ c$, the other of $c\ d$. The first being the simplest, we will take the origin at b.

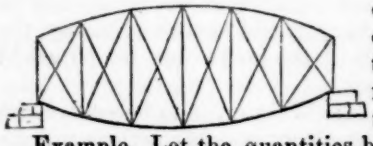
Considering as before the forces at the right of the section, and we have to consider the strains on the infinitely short parts of the bars $a\ b$, $b\ c$, and $c\ d$. To produce tension on this part of $b\ c$ the force acts from b towards c. Therefore we have $a_2 = 90° + \theta$ and the other angles as before. These in (10) give

$$\left.\begin{aligned} \mathrm{F}\cos i - \mathrm{F}_1\cos i_1 - \mathrm{F}_2\sin\theta &= 0 \\ \mathrm{F}\sin i - \mathrm{F}_1\sin i_1 + \mathrm{F}_2\cos\theta &= \mathrm{V} - \Sigma_o^{x_1} \mathrm{P} \\ \mathrm{F}_1 h\cos i_1 &= \mathrm{V}x_1 - \Sigma_o^{x} \mathrm{P}x \end{aligned}\right\} \quad . \quad . \quad (12)$$

Equations (12) may be deduced from (10) by substituting minus θ for θ. Equations (10) or (12) are applicable to Fig. 4 by observing the signs of the angles. It must be observed that at the left of the middle the signs of i and i_1 change and become negative.

9°. *Let the lower chord be convex downwards*, as in Fig. 6. Equations (10) are immediately applicable by observing that at the right of the middle, i is positive, i_1 negative and θ positive or negative according to the inclination of the bar; while at the left of the middle, i is negative and i_1 positive.

Fig 6



Example. Let the quantities be as in the preceding example, only observe that the inclination of the lower chord is—20°, and we find from (10) that for a load over the whole length;

$$\mathrm{F} = 218,\ \mathrm{F}_1 = 143,\ \text{and}\ \mathrm{F}_2 = -107.$$

The negative value of F_2 indicates that it is a tie.

10°. The same equations apply to the case where the upper chord is convex downwards and the lower convex upward as in Fig. 7, by observing the signs of the angles.

Fig 7

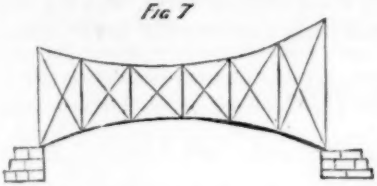
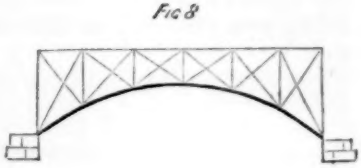


Fig 8



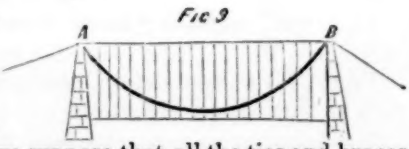
11°. Let the upper chord be horizontal and the lower one convex upwards as in Fig. 8.

Make $i = 0$ in (10) and call the horizontal force in the upper chord H and (10) becomes

$$\left.\begin{aligned} &F_1 \cos i_1 + F_2 \sin \theta = H \\ &F_1 \sin i_1 + F_2 \cos \theta = V - \Sigma_0^{x_1} P \\ &F_1 h \cos i_1 \qquad\quad Vx_1 - \Sigma_0^{x} Px \end{aligned}\right\} \quad . \quad . \quad (13)$$

At the left of the middle, i_1 is negative.

Fig 9



12°. Let the lower chord be convex downwards.

In this case we have only to change the sign of i_1 in (13). If we suppose that all the ties and braces are omitted—or what is equivalent, suppose $\theta = 0$—we shall have the analytical condition of the suspension bridge. Making i_1 negative and $\theta = 0$ in (13) and we have

$$\left.\begin{aligned} &H = F_1 \cos i_1 = 0 \\ &F_1 \sin i_1 + F_2 = V - \Sigma_0^{x_1} P. \\ &F_1 h \cos i_1 \quad = Vx_1 - \Sigma_0^{x} Px \end{aligned}\right\} \quad . \quad . \quad (14)$$

In the suspension bridge the land cables resist the strain which is now thrown upon the chord AB, Fig. 9. From the first of these we observe that for $i_1 = 0$; $H = F_1$ *i.e.* at the lowest point the tension of the cable equals the compression of the upper chord. Also from the first $F_1 \cos i_1 = H$, that is, the horizontal component of the tension at any point equals the tension at the lowest point, and this is true whether the curve be parabolic, catenarian, or any other form.

From the second of (14) we have

$$F_1 \sin i_1 = V - \Sigma_0^{x_1} P - F_2$$

in which F_2 may be included in $\Sigma_0^{x_1} P$, and thus not appear as a separate term. Hence we have

$$F_1 \sin i_1 = V - \Sigma_0^{x_1} P \quad . \quad . \quad (15)$$

which shows that the vertical force resolved by the arch (or cable) at any point equals the portion of the load which is supported by the pier generally diminished by all the load between it and the same

pier; or equal the load between the lowest point of the curve and the point considered.

If the load and ties be considered continuous, and the loading follow any algebraic law, the cable will be a continuous curve, and the preceding equations may be more conveniently expressed in the following way:

Let $f(x\ y)$ be the equation of the curve,

s any portion of the arc,

$T = F_1 =$ tension at any point

then $\cos i_1 = \frac{dx}{ds}$ $\sin i_1 = \frac{dy}{ds}$

Hence, (14) and (15) become

$$\left.\begin{aligned} T\frac{dx}{ds} &= H \\ T\frac{dy}{ds} &= V - \Sigma_0^{x_1} P \\ Th\frac{dx}{ds} &= V^{x_1} - \Sigma_0^{x} Px \end{aligned}\right\} \quad . \quad . \quad (16)$$

From (16) we may determine the mechanical conditions of the cable such as tension and deflection.

For instance suppose the load is uniformly distributed over the span, and

Let $L =$ the length of span,

$w =$ the load on a unit of length, and take the origin at the lowest point.

Then $V = \frac{1}{2} w L$; $\Sigma_0^{x^1} P = w(\frac{1}{2} L - x)$. These substituted in the second of (16) and then differentiated gives

$$d T\frac{dy}{ds} = w dx \quad . \quad . \quad . \quad . \quad (17)$$

The value of T from the first of (16) substituted in (17) gives

$$d H\frac{dy}{dx} = w dx \text{ the integral of which}$$

is $$x^2 = \frac{2H}{w} y \quad . \quad . \quad . \quad . \quad (18)$$

which is the equation of a parabola.

Equation (18) aids us in using the third of equation (16), but the latter is rarely necessary, when the equation of the curve is known.

Equation (18) and the third of (16) give the same value for H at the lowest point. For at the lowest point $x = \frac{1}{2} L = x_1$, $y = h = D$

$$\frac{dx}{ds} = 1 \qquad \Sigma_0^{x} Px = \tfrac{1}{2} wL \times \tfrac{1}{4} L = \tfrac{1}{8} wL^2$$

$$V = \tfrac{1}{2} wL$$

which in the third of (16) gives

$$T = H = \frac{\frac{1}{4} w L^2 - y w L^2}{D} = \frac{w L^2}{8D} \quad . \quad . \quad (19)$$

which is the same that we obtain directly from (18). The same result may be obtained geometrically.

We would proceed in a similar way if the loading follows any other law. If the loading be the cable itself—forming a catenary—we have $V - \Sigma_0^{x_1} P = \int \delta K ds$, when δ is the weight of a unit of volume and K the section of the cable.

If the load increases uniformly from the middle each way, then $V_0^{x_1} \text{ or } -P = \frac{1}{2} w x^2$

13°. If the lower chord be horizontal and the upper one convex upwards, we have $i_1 = 0, F_1 = H_1$ in (10), which will give

$$\left.\begin{aligned} F \cos i + F_2 \sin \theta &= H_1 \\ F \sin i + F_2 \cos \theta &= V - \Sigma_0^{x_1} P \\ H_1 h &= V x_1 - \Sigma_0^{x_1} P x \end{aligned}\right\} \quad . \quad . \quad . \quad (20)$$

The equations thus far deduced are for the most general distribution of the load. Let us now suppose that the load is uniformly distributed over a part or the whole of the span, being continuous from one end to the point considered,—or from end to end,—as the case may be. If the load extends from end to end we readily have

$$\left.\begin{aligned} V &= \tfrac{1}{2} w L; & \Sigma_0^{x_1} P &= w x_1 \\ V x_1 &= \tfrac{1}{2} w L x_1 & \Sigma_0^{x_1} P x &= \tfrac{1}{2} w x_1^2 \end{aligned}\right\} \quad . \quad . \quad . \quad (21)$$

If it extends from the remote end to the point considered—thus giving the maximum shearing,—we have

$$\left.\begin{aligned} V &= \frac{w(L - x_1)^2}{2L} & \Sigma_0^{x_1} P &= 0 \\ V x_1 &= \frac{w(L - x_1) x_1^2}{2L} & \Sigma_0^{x_1} P x &= 0 \end{aligned}\right\} \quad . \quad . \quad . \quad (22)$$

It is impossible to strictly realize the latter condition, for the weight of the frame always forms an appreciable part of the load, and may be considered a permanent load, while the surcharge may be called *moveable* or *transient*.

These may be considered separately or together. If separately, we shall have for the case of maximum shearing arising from the surcharge, from (20)

$$\left.\begin{aligned} F \cos i + F_2 \sin \theta &= H_1 \\ F \sin i + F_2 \cos \theta &= V \\ H h &= V x_1 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (23)$$

The 1st and 2d of (23) are the same as (3) and (2) page 224 of the April number of the *Journal* for this year.

The weight of the frame cannot be definitely known until the

strains upon the several parts are known, but these cannot be known until the load is known; hence the strains due to the weight of the frame remain an implicit function of the weight. We may, however, approximate to the weight by assuming that it is an uniform load, and then finding the sections of the principal parts at the middle of the frame. This assumption will not be far from the truth, and will generally be on the side of safety. I give the following as one method of finding the approxmate weight.

Let K = the section of the upper chord at the middle which also equals the section of the lower one,
L = the total length of span,
D = the depth of frame at the centre.
δ = the weight of a unit of volume of the frame,
n = the ratio between the weight of a chord and the whole weight of the frame.

Then the weight of the frame equals $n\,\delta\,K\,L$

and $V = \frac{1}{2}\,n\,\delta\,K\,L$

Fig 10

Let a section be made at the middle of the frame, and taking A as the origin of moments and we have

$\frac{1}{2}\,n\delta KL \times \frac{1}{4}L$ = the moment of the frame,

$\frac{1}{8}wL^2$ = the moment of the surcharge.

Hence the equation

$$HD = \tfrac{1}{8}n\delta KL^2 + \tfrac{1}{8}wL^2$$

$$\therefore\ H = \frac{n\delta KL^2 + wL^2}{8D} \qquad . \quad . \quad . \quad . \quad . \quad . \quad (24)$$

But this horizontal force must be resisted by the material. If c be the resistance to crushing of a unit of section, we have

$$cK = H = \frac{n\delta KL^2 + wL^2}{8D}$$

$$\therefore\ K = \frac{wL^2}{8cD - n\delta L^2} \qquad . \quad . \quad . \quad . \quad (25)$$

For cast iron $\delta = 0{\cdot}25$ lbs. per cubic inch,
for wrought iron $\delta = 0{\cdot}27$ lbs. per cubic inch,
for wood $\delta = 0{\cdot}03$ lbs. per cubic inch,

and n may be 3, 4, 5, or 6, according to the nature of the structure.

Although the weight of the frame may be considered an uniform load, yet it produces very different strains in different structures. For instance, if the upper chord be a parabola, so much of the chord as is really an uniform load produces no strains upon the ties and braces; while the lower chord and ties strain the ties and braces.

If the chords are parallel they produce the same or *very nearly* the same, strains as an uniform surcharge. It is *safe* to consider the effect in most practical cases the same as for an uniform surcharge, and I shall so consider it hereafter.

Although the load may be continuous, yet it is really supported

at the joints where the ties and braces are connected with the chords; and the same effect would be produced upon the trussing if the load were divided into as many equal weights as there are bays, and each weight were supported directly by the ties and braces. This hypothesis will enable us to slightly modify the preceding equations. They may also be modified for many forms of trusses so as to be more convenient for computation. These modifications will form the subject of the next article.

(To be Continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

Note on the Variations of Density produced by Heat in Mineral Substances. By Dr. T. L. Phipson, F.C.S.

From the London Chemical News, No. 235.

That any mineral substance, whether crystallized or not, should diminish in density by the action of heat, might be looked upon as a natural consequence of dilation being produced in every case and becoming permanent. Such diminution of density occurs with idocrase, Labradorite, feldspar, quartz, amphibole, pyroxene, peridote, Samarskite, porcelain, and glass. But Gadolinite, zircons, and yellow obsidians augment in density from the same cause. This again may be explained by assuming that, under the influence of a powerful heat, these substances undergo some permanent molecular change. But in this note I have to show that this molecular change is not permanent, but intermittent, at least as regards the species I have examined, and probably with all the others. Such researches, while tending to elucidate certain points of chemical geology, may likewise add something to our present knowledge of the modes of action of heat. My experiments were undertaken to prove an interesting fact announced formerly by Magnus—namely, that specimens of idocrase after fusion had diminished considerably in density without undergoing any change of composition: before fusion their specific gravity ranged from 3·349 to 3·45, and after fusion only 2·93 to 2·945. Having lately received specimens of this and other minerals brought from Vesuvius in January last by my friend Henry Rutter, Esq., I determined upon repeating this experiment of Magnus. I found, first, that what he stated for idocrase and for a specimen of reddish-brown garnet was also the case with the whole family of garnets as well as for the minerals of the idocrase groupe; secondly, that it is not necessary to melt the minerals: it is sufficient that they should be heated to redness without fusion, in order to occasion this change of density; thirdly, that the diminished density thus produced by the action of a red heat is not a permanent state, but that the specimens, in the course of a month or less, resume their original specific gravities. These curious results were first obtained by me with a species of lime garnet in small yellowish crystals, exceedingly brilliant and resinous, almost granular, fusing with difficulty to black enamel, accompanied with very little

leucite and traces of grossular, and crystallized in the second system. Specimens weighing some grammes had their specific gravity taken with great care, and by the method described by me in the *Chemical News* for 1862. They were then perfectly dried and exposed for about a quarter of an hour to a bright red heat. When the whole substance of the specimen was observed to have attained this temperature, without a trace of fusion, it was allowed to cool, and when it had arrived at the temperature of the atmosphere, its specific gravity was again taken by the same method as before. The diminution of density being noted, the specimens were carefully dried, enveloped in several folds of filtering paper, and put aside in a box along with other minerals. In the course of a month it occurred to me that it would be interesting to take the specific gravity again, in order to ascertain whether it had not returned to its original figure, when, to my surprise, I found that each specimen had effectively increased in density and had attained its former specific gravity. Thus:

Lime garnet mellitite (from Vesuvius).

	Original Density.	Density after being heated red-hot for a quarter of an hour and allowed to cool.	Density determined in a month after the experiments.
I.	3·345	2·978	3·344.
II.	3·350	2·980	3·350.
III.	3·349	2·977	3·345.

The same experiments were made with several other minerals belonging to the idocrase and garnet family, and always with similar results. Now I ask, what becomes of the heat that seems to be thus shut up in a mineral substance for the space of a month? The substance of the mineral is dilated, the distance between its molecules is enlarged, but these molecules slowly approach each other again, and in the course of some weeks resume their original positions. What induces the change, or how does it happen that the original specific gravity is not acquired immediately the substance has cooled?* Will the same phenomenon show itself with other families of minerals or with the metallic elements? Such are the points which I propose to examine in the next place; in the mean time the observations I have just alluded to are proof that bodies can absorb a certain amount of heat not indicated by the thermometer (which becomes latent), and that this is effected without the body undergoing a change of state; secondly, that they slowly part with this heat again until they have acquired their original densities; thirdly, so many different substances being affected by a change of density when melted or simply heated to redness and allowed to cool, it is probable this property will be found to belong, more or less, to all substances without exception.

* Some minerals, like euclase, that become electric by heat, retain that state for a considerable time. The increase of density of Gadolinite and the decrease of density of Samarskite by action of heat, are accompanied by a vivid emission of light, as mentioned in my work on "Phosphorescence," &c., pp. 31 and 32, where H. Rose's ingenious experiment is described.

Proceedings of the Royal Society, May 26, 1864.

On the Pressure of Steam at high Temperatures. By R. A. Peacock, C.E.

From the London Artizan, Feb., 1864.

(Continued from page 124.)

The reader has now the means of forming his own opinion as to the degree of reliance which can be placed on the formula. That is to say, if he accepts Dr. Fairbairn's temperature with the respective pressures of 56·7 and 60·6 lbs, and discards M. Regnault's temperatures, which are about $\frac{2}{3}$ of a degree Fahr. greater for equal pressures, then the formula will be as accurate as could be expected or even wished for. Because we should have as follows:—

Pressure.		Temperature. Fahrenheit.	Formula.	Differences.
lbs. per sq. in.				
30	M. Regnault	250·23	250·17	+·06
56·7	Dr. Fairbairn	288·25	288·20	+·05
60·6	Ditto	292·53	292·48	+·05
300	M. Regnault	417·50	417·32	+·18
336·3	Dr. M. Rankine*	428·00	428·05	−·05

These differences are exceedingly small. But if on the other hand, any reader rejects Dr. Fairbairn's experiments aforesaid and adopts M. Regnault's table throughout, the formula will be valueless to him for pressures greater than about 400 lbs to the square inch. Because M. Regnault's table gives a temperature less than the formula by ·24 for 25 lbs, this differance gradually diminishes with increasing pressures until at 29 lbs the table and the formula are exactly equal. With higher pressures the table gives temperatures in excess of the formula, which excess gradually increases until it attains its maximum of ·73° Fahr. at 80 lbs, after which the excess gradually diminishes, until the table and formula would be identical at about 320 lbs pressure. After which the formula would be in excess of the table, which excess would be greater and greater, until, as aforesaid, at about 400 lbs. pressure, the formula would cease to be of any value to the reader in question. These variances will be more readily apprehended by considering the following diagram, where the full line represents the temperatures in M. Regnault's table, and the dotted the temperatures of the formula:—

* This is supposing Dr. M. Rankine's to be an experiment and not a calculation.

By which it will be seen that the formula, after about 400 lbs, will necessarily diverge more and more from the table. The diagram shows the *manner* of the discrepancy, greatly exaggerated in *degree*.

The formula is as follows:—It has been stated that the temperature increases as the $4\frac{1}{2}$ root of the pressure in lbs per square inch. Now for a pressure of 29 lbs. to the square inch both M. Regnault's table and formula give the same temperature, viz: 248·3°, let it therefore be assumed accordingly as a basis to commence from. We shall then have by the formula, supposing the temperature to give a pressure of 300 lbs. is required—

$$\frac{\text{log. of 29 lbs.}}{4{\cdot}5} : \text{log. of } 248{\cdot}3^\circ :: \frac{\text{log. of 300 lbs.}}{4{\cdot}5} : \text{log. of } 417{\cdot}32^\circ$$

which is the temperature required, as per table appended hereto. But this process may be shortened. The following is the working formula and gives the same results with half the labor, which is of importance where the calculations are numerous. By it the following table was calculated. No basis is required, the temperature is ascertained at once by adding the constant log. 2·07, which is equivalent to adding the second term and deducting the first.

Working formulas.—When the temperature to produce a given pressure is required:—

Rule.—Divide the log. of the given pressure by 4·5, and add log. 2·07; the sum is the log. of the temperature required.

Example.—Required, the temperature to produce a pressure of 29 lbs per square inch?

$$\frac{\text{log. of 29 lbs.}}{4{\cdot}5} + 2{\cdot}07 = \text{log. of } 248{\cdot}3^\circ \text{ the temperature required.}$$

Or when the pressure produced by a given temperature is required, we have only to reverse the operation. Thus, let it be required what pressure per square inch will a temperature of 417·32° Fahr. produce? Here we have

$$\text{log. of } 417{\cdot}32^\circ - \text{log. } 2{\cdot}07 \times 4{\cdot}5 = \text{log. of } 299{\cdot}93 \text{ lbs.}^*$$

the pressure required.

Or, again, let it be required what will be the pressure of steam of a temperature of 3000° Fahr. which Sir W. G. Armstrong assumed as the temperature of subterranean fusion in his address to the British Association.

$$\text{log. of } 3000^\circ = 3{\cdot}4771213 - 2{\cdot}07 = 1{\cdot}4071213 \times 4\tfrac{1}{2} = 6{\cdot}3320458 =$$

2,148,050 lbs. = 959 tons per square inch,

if the formula can be depended on so far, and it would be difficult to prove either an affirmative or a negative, if we adopt Dr. Fairbairn's experiments.

It thus appears that by first ascertaining the temperature of saturated steam in a boiler, we at once get the pressure. Professor Daniell, F.R.S., ascertained the heat of a common fire to be 1141°

* The correct temperature by the rule for 300 lbs. is not 417·32°, but 417·322+°.

Fahr.; this would give by the formula a pressure of upwards of 12 tons per square inch. Now, supposing an ordinary boiler, made of $\frac{3}{8}$ boiler plate; of course the strength of the plates would be reduced in strength at the joints by the rivet holes, and additionally by the length of the boiler, if that was considerable—short boilers being much stronger than long ones—a plate here and there would also be sure to be defective. All this being considered, there is no reason for surprise that such boilers should burst where the pressure may be of any amount up to, and even exceeding, 12 tons per square inch. At the same time, it is probably quite true that explosions sometimes take place from other causes than excessive pressure of steam directly on boiler plates.

Dr. Fairbairn's experiments on the tensile strength of rivet iron prove that iron may be heated up to about 400° Fahr. without impairing its strength.* This temperature gives a pressure of 250 lbs. per square inch. Now, if steam can be conveniently and economically heated up to this point (which ought not to be exceeded), it follows that boilers might be made much smaller than they are at present, where the pressure often does not exceed one-tenth part of 250 lbs. In that case, of course, the boilers must be made much stronger; they might, in fact, be made of thin armor plates of Bessemer's steel, joined together with double rows of rivets first, and then be properly bound together with steel bars.

To ascertain the steam pressure correctly, the following plan might be adopted. Provide a coiled steel spring suitably strong, carrying an index, and contained in a case or cavity like an ordinary letter weigher. Place actual weights of different amounts on the top of the brass piston, and graduate accordingly. This will prevent mistakes about the actuality of the pressure indicated. Insert the top of this piston of one inch square, on which the steam is to act, through the top plate of the boiler, and fix the instrument firmly there in an inverted position, the index and spring being outside the boiler. The piston may work through a stuffing box. In like manner a thermometer may be affixed, the bulb being inside the boiler. Thus the pressure and temperature can both be read off. The pressure, as has been said, must not be allowed to get above the 250 lbs., so that the boiler would be quite safe from bursting. This plan would apparently settle the question of boiler explosions; and, the boiler being small, it would not be out-of-the-way expensive, notwithstanding its being made of steel and unprecedentedly strong. In this case the specific volume of the steam, or the ratio of the volume of the steam to that of the water which produced it, would be, according to Dr. Fairbairn's formula, 123·76.

For the purpose of exhibiting in the following table that the temperature gradually increases with the pressure, which ought clearly to be the case if the calculations are correct, the whole of the calculations are given. This will also enable any one to make a comparison between the best known experiments and the calculations.

* "Useful Information for Engineers," second series, p. 124.

TABLE of Pressures and corresponding Temperatures of Saturated Steam, calculated on the theory that the temperature increases as the $4\frac{1}{2}$ *root* of the pressure, and conversely that the pressure increases as the $4\frac{1}{2}$ *power* of the temperature.

Pressure.	Calculation.	Pressure.	Calculation.	Pressure.	Calculation.
lbs. per sq. in.	Temp. Fahr. deg.	lbs. per sq. in.	Temp. Fahr. deg.	lbs. per sq. in.	Temp. Fahr. deg.
25	240·24	53	283·90	145·8	355·50
26	242·34	54	285·08	147	356·14
26·5	243·37	55	286·25	150	357·75
27	244·39	55·9	287·28	154·3	360 (1)
27·4	245·19	56	287·40	160	362·91
27·6	245·59	56·7	288·20	163·3	364·56
28	246·37	57	288·53	165	365·40
28·83	247·98	58	289·65	170	367·84
29	248·30	58·8	290·53	170·99	368·31
29·4	249·05	59	290·75	180	372·54
30	250·17	60	291·84	182·4	373·63
31	252·01	60·4	292·27	190	377·04
31·458	252·83	60·6	292·48	195	379·22
32	253·81	65	297·08	200	381·37
33	255·53	66·15	298·23	203·3	382·75
33·1	255·71	67·23	299·31	210	385·52
33·71	256·74	69·21	301·25	220	389·52
34	257·23	70	302·01	225	391·48
35	258·90	73·5	305·30	225·9	391·82
36	260·52	75	306·67	230	393·39
36·75	261·70	79·03	310·26	240	397·13
37	262·11	80	311·10	250	400·75
37·8	263·36	80·85	311·83	252·619	401·68
38	263·67	85	315·32	254·089	402·20
39	265·57	88·2	317·92	255	402·52
39·25	265.57	89·86	319·24	260	404 26
40	266·70	90	319 35	270	407 67
40·3	267·14	95	323·22	272 008	408·33
41	268·16	95·516	323·61	280	410·97
41·7	269·17	95·55	323·63	285	412 60
42	269·60	100	326·92	290	414·19
42·196	269·88	101·9	328·28	300	417·32
43	271·02	102·9	329·01	315	421·87
44	272 40	105	330·49	316 858	422·42
44·1	272·54	108·4198	332 84	330	426 25
45	273·77	110	333·92	336·3	428·05
45·49	274·43	110·25	334 08	345	430·48
45·7	274·70	115	337·24	351·8298	432·36
46	275·11	115·1	337·30	360	434·58
47	276·42	120	340·44	375	438·54
48	277·72	124·95	343 51	400	444 87
49	279·	125	343·54	420	449·72
49·4	279·50	129·8	346·43	440	454·40
50	280·25	130	346 55	450	456 67
51	281·49	132·3	347·90	460	458·91
51·45	282 02	135	349·47	480	463·27
51·7	282·34	139·65	352·11	500	467·49
52	282·70	140	352·30	520	471·58(2)
52·52	283 33	145	355 06	540	475·55

[1] Soft solder, two parts tin and one part lead, melts at 360°.

[2] Bismuth melts, 471·6°. (Dixon on heat.)

Pressure.	Calculation.	Pressure.	Calculation.	Pressure.	Calculation.
lbs. pr sq.in.	Temp. Fahr. deg.	lbs. pr sq.in.	Temp. Fahr. deg.	pr sq.in. Tons. lbs.	Temp. Fahr. deg.
550	477·49	1900	628·94	8¼	1049·63
560, ¼ ton	479·41	1984	635 (2)	8¾	1056·41
580	483·16	2000	636·15	9	1063·05
600	486 82	2055	640 (3)	9¼	1069·54
620	490·38	2100	643·09	9½	1075·90
635	492·99	2200	649·77	9¾	1082·13
650	495·56	2240, a ton	652·37	10	1088·23
660	497·24	Tons. lbs.		10¼	1094·22
680	500·55	1 152	662 (4)	10½	1100·10
700	503·78	1¼	685·54	10¾	1105·86
720	506·95	1½	713·89	11	1111·53
740	510·04	1¾	738·77	11¼	1117·09
750	511·57	2	761·02	11½	1122·56
760	513·08	2¼	781·20	11¾	1127·94
780	516·04	2½	799·71	12	1133·23
800	518·96	2¾ 73	802 (5)	12¼	1138·43
820	521·81	2½ 332	810 (6)	12 839	1141 (8)
840	524·61	2¾	816·82	12¼	1143·50
850	526	3	832·77	12¾	1148·60
860	527·36	3¼	847·72	13	1153·56
880	530·06	3½	861·80	13¼	1158·46
900	532·71	3¾	875·11	13½	1163·28
920	535·33	4	887·75	13¾	1168·03
940	537·89	4¼	899·79	14	1172·72
950	539·16	4½	925·37	14¼	1177·34
960	540·41	4¾	932·30	14½	1181·90
980	542·90	5	932·88	14¾	1186·40
1000	545·34	5¼	943·05	15	1190·84
1050	551·28	5½	952·85	15¼	1195·22
1100	557·01	5¾	962·31	15½	1199·54
1120, ½ ton	559·25	6	971·45	15¾	1203·82
1200	567·89	6¼	980·30 (7)	16	1208·04
1279·09	576· (1)	6½	988·88	17	1224·42
1300	578·08	6¾	997·21	18	1240·07
1400	587·68	7	1005·31	19	1255·06
1500	596·76	7¼	1013·17	20	1269·45
1600	605·38	7½	1020·84	25	1334
1680, ¾ ton	611·98	7¾	1028·30	30	1389·15
1700	613·59	8	1035·58	50	1556·14
1800	621·43	8¼	1042·69	100	1815·28

[1] Lead melts, 576°.
[2] Iron, red heat in the dark, 635°.
[3] Linseed oil boils, 640°.
[4] Mercury boils, 662°.
[5] Charcoal burns, 802°.
[6] Antimony melts, 810°.
[7] Iron, dull red heat, 980°.
[8] Heat of a common fire, 1141°

The following are the several melting heats of some of the more refractory metals, with the pressures of steam of equal temperatures calculated by the formula:—

Calculations of Pressure in Tons per square inch.			
114	Brass melts at	1869° [11]	Fahr.
115	Silver "	1873° [12]	"
153	Copper "	1996° [13]	"
237	Gold "	2200° [14]	"
326	. .	2360° [15]	"
687	Cast iron "	2786° [16]	"
959	Subterranean fusion	3000° [17]	"

The temperatures marked [5], [7], [8], [9], [10], [11], [12], [13], [15], are on the authority of Professor Daniell, F.R.S. [15], the temperature 2360°, is stated by Dr. Macquorn Rankine, F.R.S., to be that about at which the water in an engine boiler would be totally evaporated. (*Artizan* Nov., 1863, p. 252.) [17] In Sir W. G. Armstrong's address to the British Association, at Newcastle (p. 9), he assumes the temperature of the subterranean fusion to be 3000° Fahr. The other melting points, &c., have been obtained from a small volume on steam, published by the late Mr. Weale.

Earthquakes, Volcanic Explosions and Upheavals of Strata.—There is another point of view in which this formula may possibly be not without interest to a class of scientific men, other than engineers. More than a century ago the Rev. John Michell, M.A., "conjectured" that steam might be the cause of earthquakes, and he reasons very ably at considerable length on the subject.* His idea, however, seems to have been dropped, except by a very few, by whom it is entertained only as one out of several conjectural causes. Now if, as must now and then happen, fissures open in the bed of the sea, by the action of earthquakes and close again after a few seconds or minutes, it follows that a large body of water will rush down and be imprisoned, and come in contact with the fused matter below. This water will necessarily be converted into steam, which will only remain quiescent as long as it is everywhere surrounded by a resistance greater than its own expansive force. If the formula approximates towards the truth, unless the resistance amounts to a thousand tons per square inch or thereabouts on every side, in certain cases an explosion will take place of sufficient force to account for an earthquake or volcanic eruption, as the case may be. In reading accounts of volcanoes and earthquakes, it will frequently be observed that *hot water* and *steam* are ejected, to say nothing of the *hot water* and *steam* which notoriously issue from boiling springs and geysers. The writer has made a considerable collection of such cases. There is then plenty of direct proof of the existence of steam in the bowels of the earth, and steam will not be idle if it can find any point of less resistance than its own expansive force. Therefore, in considering the cause or causes of earthquakes, volcanic explosions, and upheavals of strata, you cannot get rid of steam. For let us look from whatever point of view we will the pressure of saturated steam must be enormous long before it reaches the temperature of 3000 degrees.

—

SIR:—The figures quoted by Mr. Peacock, in *The Artizan* for January, [*Jour. Fr. Inst.*, vol. xlviii. page 123,] from a table of mine in *The Artizan* for November last, are not to be regarded as independent data respecting the temperatures corresponding to various pressures of high pressure steam. They are merely a few of the results of a formula which I deduced from M. Regnault's experiments, and published in 1849; and they may be regarded as practically identical with the results of those experiments. W. J. MACQUORN RANKINE.

Glasgow, January 1864.

* Phil. Trans. R.S. 1760. Vol. II, p. 447, &c.

On the Supposed Nature of Air prior to the Discovery of Oxygen.

By George F. Rodwell, F.C.S.

From the London Chemical News, No. 217.

(Continued from page 259.)

5. *Boyle's Experiments continued.—Experiment* 17.*—A tube three feet long and a quarter of an inch in diameter, closed at one end, was filled with mercury, and inverted in a vessel of the same metal; the latter was placed within the air-pump receiver, and the tube passed air-tight through its cover; on exhausting, the mercury fell nearly to a level with that in the vessel; but the same level within and without the tube could never be attained, because when the exhaustion was carried on for some length of time, air leaked into the receiver in spite of every precaution. When a quart receiver was used, the first downward stroke of the piston withdrew sufficient air to cause the column to fall eighteen and a-half inches. The falling of the mercury was not, however, entirely due to the removal of pressure, because a minute quantity of air was always present in the space above the mercury, and by its expansion the mercury column would be depressed. The mercury was never boiled in the tube in these early experiments, hence there was always a small amount of air, which was mechanically retained by the mercury, and rose into the so-called vacuum, when the tube was inverted. Boyle states that, when the tube was inclined, the mercury never reached quite to the top of it, and when a hot iron was held near that part of the tube above the mercury, a slight depression of the column was apparent.

Experiment 18—The height of the mercury column in Torricelli's tube was found to vary from day to day, and it did not vary in conformity with the weather-glass. According to Boyle the variation may be caused by ebbings and flowings in the atmosphere, and by sudden changes in its height and density, produced by causes with which we are unacquainted. That changes do take place, he considers is proved by the fact, that the refracting power of the air varies; and miners had related to him that a certain steam, called by them a "damp,"† sometimes arises within mines, and possesses such "thickness" that it extinguishes candles; it may also happen, he says, that fumes ascend from the earth with such rapidity, that the air through which they pass is dragged upwards by them, and a consequent diminution of pressure on that part of the earth beneath the ascending currents, takes place.

Mr. Wren, being asked by Boyle to mention any experiment relative to the pressure of air which he would wish to be tried, said it would be of importance to observe if the height of the mercury column

* This experiment, as mentioned in the third of these papers, was tried by a different but far more complete method by Pascal; we must bear in mind, however, that this treatise "On the Weight of the Mass of Air," was not published till 1663, whereas Boyle's "Physico-Mechanical Experiments," appeared in 1661. Pascal undoubtedly, made the experiment first, but Boyle was probably unaware of the fact.

† From the German "dampf,"—vapor, steam, fume.

varied according to the tides, inasmuch as, if it did not do so, Des Cartes' theory, that tides are produced by the increased pressure communicated to the air by the moon at certain times of the day than at others, would be disproved. Boyle did not find the height of the column affected by the state of the tides.

Experiment 19.—Having observed, in experiment 17, to what extent a column of mercury could be made to fall on the removal of pressure, Boyle next tried the same experiment with a column of water, contained in a tube four feet long. On exhausting, the water fell to within a foot of the surface of the water in the vessel into which the open end of the tube dipped. When air was re-admitted into the receiver, water was driven violently to the top of the tube.

In the 21st experiment Boyle declares he will not say for certain "whether or no air be a primogenial body," incapable of conversion into water; for, although many have affirmed that when water is heated it becomes air, he has observed in chemical distillations that the vapor of water quickly returns to water; and, in the Musæum Kircherianum, Schottus states there is a hermetically sealed glass vessel half full of water, which had been sealed for fifty years, without the water becoming air. On the other hand, however, it appears that air can be produced, because, when a number of iron nails were placed in a mixture of oil of vitriol and water, Boyle found that a quantity of air was evolved, and, although this does not prove that water may become air, it proves, he considers, that air may be generated.

If, by any chance, Boyle had brought a candle near his newly-generated air, what a wide field would have been opened to him when he found that there were other airs differing from "the air;" but the possibility of there being different kinds of air does not seem to have entered his head; for even carbonic acid gas, although so totally different from ordinary air, was only distinguished by him as "thickened air."

Experiment 27.—A watch was suspended by a thread in the air-pump receiver; on exhausting, the ticking ceased to be heard; but when air was re-admitted, it was heard as distinctly as before exhaustion.

A bell was supported in the receiver by a bent stick, the ends of which pressed against the sides of the receiver; when the latter was exhausted, and the bell rung, the sound was distinctly audible; hence Boyle concluded that sound can be conveyed by some rarer medium than air.

This is one of many examples of the great disadvantages under which the early experimenters labored, and we must make every allowance for the false conclusions at which they sometimes arrived. When Boyle made this experiment, very little was known about the nature of sound; there were no previous experiments to tell him that the thread would not convey the vibrations to the receiver, whereas the stick would do so, and he, therefore, could have no reason for believing that there would be any difference in the result obtained, whether he suspended his sounding body by a thread or by a piece of

wood, and yet perfectly contrary effects were produced, and he was thus led to a wrong conclusion.

Experiment 33—was made with a view of determining the pressure of air on a known area. The air-pump receiver was removed from the pump, and the piston forced to the top of the cylinder, the upper orifice of the latter (into which the shank of the stop-cock of the receiver fitted) being left open; weights were attached to the piston until it was drawn down. The piston was then forced to the top of the cylinder—the upper orifice of the latter closed—and weights were again attached until the piston was drawn down; the weights obviously represent the force necessary to overcome the pressure of the air, acting on the area of the piston + the force necessary to overcome the friction between the piston and pump barrel; the weight necessary to overcome the latter source of resistance having been previously determined, it was subtracted from the total weight, and it was thus found that 112 lbs. were competent to overcome the pressure of the air on the piston. The experiment was modified by drawing the piston to the bottom of the cylinder, against the pressure of the air, and seeing how much weight it would draw up—105 lbs. + the weight of the piston rod was raised.*

Experiment 34.—Reasoning by analogy from the fact that two bodies of equal weight in air, but of different bulk, when weighed in water no longer balance each other, Boyle conceived that two bodies of equal weight in air would not be so in a vacuum. He, therefore, balanced on the opposite ends of a balance, capable of turning with $\frac{1}{32}$d of a grain, a piece of cork and a piece of lead; the balance was placed in the air-pump receiver: on exhausting the cork was found to preponderate, but on re-admitting air, it continued to preponderate from some cause which Boyle was unable to discover.

Experiment 36.—It is obvious, Boyle writes, that if we could place a balance above the atmosphere, or in a vacuum, we might weigh a quantity of air in the scales of the balance, just as we weigh substances in the air. In order to put this idea in practice, he procured a small "glass bubble," about the size of a hen's egg, and sealed it hermetically. It was then fastened to one end of the beam of the balance used in experiment 34, and was counterpoised by a piece of lead. The balance was placed in the receiver; on exhausting, the vessel of air greatly preponderated, and by placing weights on the other scale of the balance, so as to drag down the air vessel, it was found that, in a vacuum, the air in the bubble weighed $\frac{3}{4}$ths of a grain. On one occasion, when the exhaustion had been continued for some time, the included air burst the bubble with violence.

Boyle here describes several experiments which he made in order to determine the relative weights of air and water. The determination had been previously made by several different methods. Galileo found water to be 400 times heavier than air; Ricciolus (by weighing a blad-

* The diameter of the piston was three inches; hence its area = 7·0686 square inches. The pressure of the air upon it would, therefore, be, in round numbers, 7·0686 × 15 lbs. = 106·020 lbs.

der of air in air),* 10,000 times; and Merseunus, 1356 times. Boyle's method was to heat a copper elopile of known weight to redness, stop up the orifice with wax, weigh, perforate the wax to allow air to enter, and weigh again; the elopile was then filled with water, and weighed. By this method water was found to be 938 times heavier than air.

Boyle next determined the relative weights of water and mercury, and found the latter to be $13\frac{92}{1}$ times heavier than the former. The relative weights of air and mercury were deduced from the above data, and were found to be as 14,000 to 1. When in possession of these facts, Boyle was able to calculate that the height of the whole atmosphere, if we suppose it to possess throughout the same density as at the surface of the earth, would be seven miles; but, he writes, knowing as we do how readily air expands when pressure is removed from it, it is not improbable that the atmosphere may extend to a height of some hundreds of miles.

Experiment 37.—Boyle frequently observed that when exhaustion was commenced the inside of the air-pump receiver became opaque, and that on the re-admission of air the opacity disappeared. We now know this phenomenon to be produced by the deposit of minute particles of water, previously existing in the state of vapor in the air. The air in expanding performs work, and a certain amount of molecular motion is converted into mass motion; consequently, the aqueous vapor in the air is condensed. When air is re-admitted, the particles strike against the sides of the receiver, and the amount of mass motion previously produced is re-converted into the molecular motion which produced it; consequently, the deposited water again becomes vapor.

Experiment 40.—In order to see whether the rarity of the air in an exhausted receiver would prevent insects from flying, Boyle placed a bee and a fly in the receiver, on exhausting, they both fell down "as in a swoon."

Experiment 41.—A lark was placed in the receiver; on exhausting, it was seized with convulsions, and although air was quickly re-admitted, it failed to revive. The pump had been worked ten minutes.

I have mentioned in the previous paper that the descriptions which Boyle gives of his experiments are exceedingly prolix; we have a good example before us in this experiment, which we should, in the present day, describe as above, but which Boyle, after telling us how he procured the bird, and how, when placed in the receiver, it did "divers times spring up in it to a good height," describes as follows: "The vessel being hastily, but carefully clos'd, the Pump was diligently ply'd, and the Bird for awhile appear'd lively enough; but upon a greater exsuction of the Air, she began manifestly to droop, and appear sick, and very soon after was taken with as violent and irregular convulsions as are wont to be observ'd in Poultry when their heads are wrung off. For the Bird threw herself over and over two or three times, and dyed with her Breast upward, her Head down-

* It is obvious, as mentioned in the first of these papers (CHEMICAL NEWS, vol. viii. p. 115), that a bladder of air, weighed in air, weighs no more than the empty bladder.

wards, and her Neck awry. And though upon the appearing of these convulsions we turn'd the stopcock, and let in the air upon her, yet it came too late; whereupon, casting our eyes upon one of those accurate Dyals that go with a Pendulum, and were of late ingeniously invented by the noble and Learned Hugenius, we found that the whole Tragedy had been concluded within ten minutes of an hour, part of which time had been imploy'd in cementing the cover to the Receiver."

We must certainly give Boyle credit for being an accurate observer and an experimenter who did not pass over the most minute occurrences without mention; but conceive what a memoir would be in the present day if it were spun out like the above account of one experiment! Why, the Royal Society would have to publish folios, and the *Philosophical Magazine* would become a thick quarto, and it would require half a lifetime to master one branch of science.

After the success of the lark experiment, Boyle placed a sparrow and a mouse in the receiver. On exhausting, they both died. In order to see whether death was produced by the "steams" from the lungs stifling the animals or from want of air, a mouse was enclosed in a large receiver. At the end of several hours it was alive and well, but died when the receiver was exhausted, proving that want of air was the cause which had produced the previous deaths.

Boyle here enters into a discussion as to the nature of Respiration. Many of the philosophers of his time believed that the sole use of respiration was the cooling and tempering the heat of the heart and blood; and this theory was not only admitted by several of the ancient writers, but by the Cartesians and numberless learned men. But, Boyle answers, fishes and frogs, and "divers cold creatures," have need of respiration; and in the above-mentioned experiments, in which animals were killed in rarefied air, it did not appear that the interior of the receiver was hotter than the external air.

Some believed that air passes from the lungs to the left ventricle of the heart, both to reduce its heat and "to generate spirits." Mæbius and Gassendus believed that the real use of the air in respiration is to ventilate the blood in its passage through the lungs, in which passage impure vapors are given off by the blood, and are removed by the air.

According to Boyle, the use of air in respiration may be explained by two methods; for, first, just as a flame is stifled when burnt for some time in a close vessel by the "fuligenous steams" which it generates, so the vital fire of the heart may require fresh air to prevent it from being extinguished; or the air in the lungs may admit into its pores the impure vapors of the blood and remove them from the lungs. "We know" he continues, "that air too much thickened is unfit for respiration, because in the lead mines of Devonshire 'damps' sometimes arise which extinguish candles, and suffocate the miners. Also, cellars in which a large quantity of new wine is set to work, men have been suffocated on account of the great thickness of the air."

That the air is "thickened" by respiration Boyle proved by enclos-

ing a bird in a small closed vessel. After three-quarters of an hour the air was found to be unfit to support life; and we can quite understand that the air must be thickened, he says, if we admit, with Sanctorius, that the quantity of matter which leaves our bodies by "insensible transpiration" exceeds in weight everything else which is given off from the body.

Air too much "thinned" is also unfit for respiration, as was proved by the death of the animals in an exhausted receiver; and Acosta states that he found some difficulty in breathing on the summit of a lofty mountain in Peru.

Although Boyle is inclined to believe that one of the uses of air in respiration is to purify the blood, by removing vapors which it throws off during its passage through the lungs, yet he conceives that it plays some other part; and Paracelsus* had a similar idea, for he affirms that just as the stomach assimilates a certain amount of meat we eat, and rejects the remainder, "*so the lungs consume part of the air, and proscribe the rest.*"

Cornelius Drebbel,† also believed that only a certain portion of air is consumed in the lungs, and it was reported that he had actually discovered that portion. It had been confidently stated to Boyle that Drebbel constructed a vessel for James I. capable of carrying twelve rowers and several passengers beneath the surface of water, and that, so soon as it was apparent that the air in the vessel had become impure from respiration, Drebbel removed the stopper from a bottle, filled with some liquid, which, by its evaporation, quickly rendered the air pure, and suitable for the purpose of respiration. This fact had been mentioned to Boyle by the friend of a man who had traveled in the vessel, by several relations of Drebbel's, and by a physician who married his daughter.

Experiment 43.—When water, wine, or oil of turpentine were heated to ebullition, and placed in the air-pump receiver, the boiling recommenced on exhausting, and continued for some time; but hot salad oil could not be made to boil.

With this experiment Boyle concludes his letter, first apologizing to Lord Dungarvan for not relating a larger number of experiments, many of which he had thought of and had wished to try, "were it not," he writes, "that my Avocations are grown so urgent for my remove from the place where the Engine was set up, that I am put to write your Lordship this Excuse, Weary, and in an Inne which I take in my way to my Dearest Brother Corke."

The account of the forty-three experiments detailed by Boyle in the treatise we have been consideirng, extends over 207 pages; but this may well be imagined from the extract given above from experiment 41.

In this first of Boyle's Pneumatic Treatises, there are an immense number of recorded facts; and when we remember the great difficulty of carrying out the experiments, we cannot too highly praise the industry and perseverance of their author. It is difficult for us, with

* Born 1493. Died 1541. † Born 1572. Died 1634.

our improved philosophical apparatus, to conceive the amount of labor attendant on the trial of experiments, 200 years ago, when the few instruments which existed were to a greater or less extent imperfect. In the present day, if we wanted to make the last experiment mentioned above, we should place our vessel of hot water on the air-pump plate, cover it with a receiver, work the pump for a few minutes, and the experiment would be finished. In order to try the same experiment Boyle had to suspend a vessel of hot water in the receiver of his air-pump, and to cement on the cover of the receiver, and, while an assistant worked the piston, to alternately open the stop-cock of the receiver, close it, open the lateral valve, close it, again open the stop-cock, and so on, till the exhaustion was as complete as it could be; the whole apparatus was meanwhile shaken with every stroke of the pump, and leakage of air at the rather numerous joints was perpetually occurring.

(To be Continued.)

For the Journal of the Franklin Institute.

On the Elements of Physical Work, Vis-viva, Force, Velocity, Time, Power, and Work. By JOHN W. NYSTROM.

The difference between *force*, *power*, and *work*, appears to be not very generally understood, as we often find the power employed and the work accomplished, confounded with each other, and that even by men of science, experience, and high standing; such as in the case of a steam hammer being said to "strike a blow of so many tons," which is substantially parallel with saying that a bushel can be so many feet in length. Professor Tyndall speaks of heat as if it was only motion, and he also converts heat into work. If motion can be converted into heat, and heat into work, then work must be convertible into motion; which is substantially the same as to convert gallons into square feet, or linear inches.

Although the physical constitution of heat is not yet known, one thing appears to be certain, namely, that heat, like work, is a function of at least three simple elements, of which velocity (motion) is one.

The heat question will be referred to at the end of the article, in the development of our subject.

In geometry we have three fundamental elements, expressed by the terms, *length*, *breadth*, and *thickness*, employed to represent to our mind the nature of those several properties of space; we have in like manner in physics, three fundamental elements, expressed by the terms *force*, *velocity*, and *time*, employed to convey to us the laws of physical work.

Quantity, is that which can be increased or diminished by homogeneous parts.

Element, is that which cannot be dissolved into two or more different quantities.

Function, is the product of two or more different elements.

Force, *Velocity*, and *Time*, are elements.

Power, *Space*, and *Work*, are functions.

Force, is the first element of work, like length in geometry. It is recognised as pressure, and measured by weight. Physical forces will herein be denoted by the letter F, and the weight of a mass or body by M.

Velocity, is the second element of work, like breadth in geometry. It is the continuous change of position, recognised as motion, and denoted by the letter V.

Time, is the third element of work, like thickness in geometry. It implies a continuous action, recognised as duration, and denoted by T.

Power is a function of the two first elements, *force* F, and *velocity* V, like area in geometry is a function of length and breadth. Force in motion produces power, like a line in motion produces a surface. Power cannot exist without the two elements force and velocity, as a surface cannot exist without length and breadth. Power is denoted by $P = F V$, measured and expressed in foot-pounds, which means a force of so many pounds moving a distance of so many feet per unit of time. One unit of power is "a force of one pound moving with a velocity of one foot per second." This unit or foot-pound has also been called effect. James Watt assumed the power of a horse equivalent to 33,000 pounds raised one foot in one minute, which is equal to 550 pounds raised one foot in one second, or 550 effects. The power of a horse is considered equivalent to that of eleven men, or the power of one man equal to 50 effects.

Space, is a function of the second and third element, *velocity* V, and *time* T, like a cross-section of a solid, is a function of breadth and thickness. Space is here denoted by $S = V T$.

Work (*vis-viva*) is the product of the three elements, *force* F, *velocity* V, and *time* T; and may be likened to a solid in geometry which has three dimensions. Work, denoted by $W = F V T$, is produced by the duration of power for a certain time, as a solid is produced by a plane in motion. Work is the product of power and time, like a solid is the product of area by thickness. *Work* cannot be produced without the three elements *force*, *velocity*, and *time*, as a *solid*, cannot exist without the three elements *length*, *breadth*, and *thickness*.

Work, appears to be the most confused function in physics, and has been denominated by a great many conventional terms, as *vis-viva*, *living force*, *energy*, *power*, *momentum*, *effect*, &c., &c. None of those terms express what is meant by the formulas assigned to them namely, $M V^2$, which means the physical work, concentrated in a moving mass, or the work required to set a body in motion.

When the formula is given, we need not care what it is called, if we only know what it is; but unfortunately when a function is denominated by a wrong and improper term, we are apt to misconceive or misapply its meaning, which has actually been the case with the improper terms for *power* and *work*.

The latin word Vis (force) and Viva (living) means "living force," which in fact is *power*, and expressed by $F V$; but when we exercise this living force for a certain duration of time, it becomes a different function, namely $M V^2$, which is *living power* or physical work, and

not merely living force. It may now be remarked that, "a living force cannot exist without some duration of time, because a living force is a force in motion, and motion requires time."

A steam engine of 100 horse power, running one day, will produce a certain amount of work; let the same engine run for only half a-day when it will produce only half the work of a whole day, but the power was still 100 horses. Let it run for only an hour, a minute, a second, or for an infinitely short period of time, the engine is still 100 horses but did no work. For that infinite small space of time, the living force was there and produced the full power F V = 100 horses but did no work M V^2. In illustration of this, let a solid cube of paper represent the work M V^2; then the base of the cube, or the bottom sheet, which we will consider to have no thickness, will represent the power F V. Take away the sheets one by one from the top of the cube—which is to reduce the time or thickness—until only the bottom sheet is left; then there is no more solidity of the cube, and no more work M V^2 left, but the power or living force F V, represented by the base of the cube is undisturbed.

There are two reasons why the true meaning of physical work has hitherto been so obscured, namely, *first*, that the primitive formula for work F V T or M V T, has been concealed by the formulas for the law of gravity, by which the time T has been transformed into velocity V, and the work represented by M V V or M V^2. Sometimes the space S has been inserted for V T, when the work has been called foot-pounds F S. We have now in scientific works two kinds of foot-pounds, without proper explanation of their difference. The foot-pounds of power, means so many pounds raised so many feet per unit of time; while the foot-pounds of work, means so many pounds raised through a space S, independent of time because the time is included in the space S = V T.

The *second* reason why it has been obscured, is that we have no established unit by which to measure physical work. We speak about *vis-viva*, the same as we would speak about length without reference to miles, feet, or inches, but merely conceive it to be, long, longer, and longest; short, shorter, and shortest.

It is therefore found necessary in the development of the subject, to establish a unit for work, and assign to it a name.

Let us assume the work accomplished by one horse power in a time of one hour, to be the unit for physical work; which will be the same as that of eleven men working one hour, or that of one man working one day of eleven hours. In order to clearly distinguish this unit from that of power, let it be called a "WORKMANDAY," which means a man's day's work. Let us further designate the quantity of physical work, or number of *workmandays* with the letter W. A workmanday expressed by force and space, without regard to time or velocity, will then be $550 \times 3600 = 1980000$ foot-pounds, or 2564·7668 units of heat. At least we will adopt this unit, name, and signature, until better shall be established by higher authority. We can now understandingly proceed to develope the physical laws of the elements of work.

All kinds of work can be estimated in workmandays, such as build-

ing a house, steamboat, or bridge, digging a canal, ploughing the ground, throwing a bomb or projectile, fighting a battle, steam-boiler explosion, &c., &c.

Momentum is the product of two or more elements.

Static momentum is a function of force and lever, or force multiplied by the length of the lever it acts upon.

Dynamic momentum is power, or the force multiplied by its velocity.

Momentum of power is physical work, or power multiplied by time.

Momentum of physical work is the cost in money, or the work multiplied by its price.

Momentum of work of art is the product of physical work and the skill of the artist.

Momentum of work of science is the product of physical work by primitive knowledge.

Notation of Letters.

S = space in feet, passed through by the force F in the time T.

F = force or pressure, expressed in pounds avoirdupois.

V = velocity or motion, expressed in feet per second.

T = time of operation in seconds.

P = power in foot-pounds, of one pound raised one foot per second.

H = horse power of 550 pounds raised one foot per second.

W = physical work, expressed in workmandays, of 1980000 foot-pounds, or 2564·7668 units of heat.

M = weight in pounds, of a moving mass, or the weight of a mass acted upon by mechanical force.

g = acceleratrix of gravity, being 32·166 feet per second, the velocity which a falling body attains at the end of its first second.

G = acceleratrix of the combined gravity and mechanical force.

v = angle with the horizon of the direction of the moving force and mass, as on an inclined plane. When the direction rises above the horizon, use the top sign, and when it deeps under use the lower sign.

L = number of laborers employed (not workmandays).

D = number of days of 11 working hours.

N = number of horses (not horse power).

n = number of blows of a steam hammer, or pile-driver.

f = friction and other incidental elements opposing the force F, or moving mass M, in pounds.

Co-efficients $550 \times 3600 = 1980000$.

" $32{\cdot}166 \times 550 \times 3600 = 63688680$.

I beg to remark here, that with a binary arithmetic and metrology, the co-efficients 550 and 3600 would disappear in the formulas, and 28 of the following formulas would also be dispensed with, say nothing of the labor and confusion it would save.

The first formula gives the theoretical value, while the last ones containing f includes friction and other incidental circumstances.

Formulas for Mechanical Work.

Space in feet passed through in the time T.

$$S=VT. \qquad S=\frac{PT}{F}. \qquad S=\frac{550TH}{F}. \qquad S=\frac{550\times3600W}{F}.$$

Force or pressure in pounds.

$$F=\frac{P}{V}. \qquad F=\frac{550HT}{VS}. \qquad F=\frac{550\times3600W}{VT}. \qquad F=\frac{550\times3600W}{S}.$$

Velocity in feet per seconds.

$$V=\frac{S}{T}. \qquad V=\frac{P}{F}. \qquad V=\frac{550H}{F}. \qquad V=\frac{550\times3600W}{FT}.$$

Time of duration in seconds.

$$T=\frac{S}{V}. \qquad T=\frac{SF}{P}. \qquad T=\frac{SF}{550H}. \qquad T=\frac{550\times3600W}{FV}.$$

Power in foot-pounds.

$$P=FV. \qquad P=\frac{FS}{T}. \qquad P=550H. \qquad P=\frac{550\times3600W}{T}.$$

Horse power.

$$H=\frac{P}{550}. \qquad H=\frac{FV}{550}. \qquad H=\frac{FS}{550T}. \qquad H=\frac{3600\,W}{T}.$$

Work, in workmandays.

$$W=\frac{FVT}{550\times3600}. \qquad W=\frac{FS}{550\times3600}. \qquad W=\frac{PT}{550\times3600}. \qquad W=\frac{HT}{3600}.$$

Number of laborers (not workmandays).

$$L=\frac{W}{D}. \qquad L=11N. \qquad L=\frac{FV}{50}. \qquad L=\frac{FS}{550\times3600D}.$$

Number of Horses (not horse power).

$$N=\frac{L}{11}. \qquad N=\frac{W}{11D}. \qquad N=\frac{FV}{550}. \qquad N=\frac{FS}{11\times550\times3600D}$$

Number of days of 11 hours each.

$$D=\frac{W}{L}. \qquad D=\frac{W}{11N}. \qquad D=\frac{50W}{FV}. \qquad D=\frac{FS}{550\times3600L}.$$

Work, in workmandays.

$$W=DL. \qquad W=HDN. \qquad W=\frac{FVD}{50}. \qquad W=\frac{F^2VS}{50\times550\times3600L}$$

Examples for Mechanical Work.

EXAMPLE 1. A steam engine of $H=145$ horses is to hoist a weight of $F=34368$ pounds. Required how high $S=?$ will the weight be lifted in $T=25$ seconds.

3d. formula for space.

$$S = \frac{550\,TH}{F} = \frac{550 \times 25 \times 145}{34368} = 58 \text{ feet the answer.}$$

EXAMPLE 2. How much coal $F = ?$ can a steam engine of $H = 36$ horses hoist up from a mine of $S = 256$ feet deep, in ten hours or $T = 36000$ seconds.

2d. formula for force.

$$F = \frac{550\,HT}{S} = \frac{550 \times 36 \times 36000}{256} = 2784375 \text{ pounds,}$$

or 1243 tons.

EXAMPLE 3. A force of $F = 378$ lbs. moving uniformly through a space of $S = 3675$ feet in $T = 490$ seconds. Required how much power P it will exert.

2d. formula for power.

$$P = \frac{FS}{T} = \frac{378 \times 3675}{490} = 2635 \text{ foot-pounds.}$$

That is, 2635 lbs. will be moved 1 foot per second.

EXAMPLE 4. The pressure on a steam piston is to be $F = 31350$ pounds. Required how fast it must move to generate a power of $H = 456$ horses.

3d. formula for velocity.

$$V = \frac{550\,H}{F} = \frac{550 \times 456}{31350} = 8 \text{ feet per second.}$$

EXAMPLE 5. What horse power $H = ?$ is required to accomplish the same amount of work in $T = 43860$ seconds, that $W = 132$ workmen could accomplish in one day?

4th. formula for horse power.

$$H = \frac{3600\,W}{T} = \frac{3600 \times 132}{43860} = 10{\cdot}82 \text{ horse power.}$$

How much work $W = ?$ is accomplished by a steam engine of $H = 164$ horses, working $T = 3496$ seconds?

5th. formula for work.

$$W = \frac{HT}{3600} = \frac{164 \times 3496}{3600} = 159{\cdot}36 \text{ workmandays.}$$

or it would require 159·36 workmen for a whole day to do the same amount of work.

EXAMPLE 6. The pressure on a steam piston is $F = 2864$ pounds, moving with a velocity of $V = 6$ feet per second during 10 hours, or $T = 36000$ seconds. Required how much work will be accomplished?

1st. formula for work.

$$W = \frac{FVT}{550 \times 3600} = \frac{2864 \times 6 \times 36000}{550 \times 3600} = 312{\cdot}44 \text{ workmandays.}$$

EXAMPLE 7. How many workmandays $W = ?$ are required to hoist up $F = 843640$ lbs. of iron to a height of $S = 45$ feet?

2d. formula for work.

$$W = \frac{FS}{550 \times 3600} = \frac{843640 \times 45}{550 \times 3600} = 1917{\cdot}3 \text{ workmandays.}$$

EXAMPLE 8. What time is required for an engine of $H = 96$ horse power, to raise a weight $F = 495000$ lbs. to a height of $S = 48$ feet?

3d. formula for time.

$$T = \frac{SF}{550H} = \frac{48 \times 495000}{550 \times 96} = 450 \text{ seconds.}$$

Formulas for Work under the action of Gravity.

Space passed through in the time T.

$$S = \frac{gT^2}{2} = \frac{VT}{2}. \quad S = \frac{PT}{2M}. \quad S = \frac{4 \times 550^2 H^2}{2gM^2}. \quad S = \frac{550 \times 3600W}{M}.$$

A mass in motion, or falling vertically.

$$M = \frac{2 \times 550 \times 3600W}{gT}. \quad M = \frac{550 \times 3300W}{S}. \quad M = \frac{2 \times 550H}{\sqrt{2gS}}. \quad M = \frac{550 \times 3600Wg}{V^2}.$$

Velocity at the end of the time T in feet per seconds.

$$V = gT = \frac{2S}{T}. \quad V = \frac{2 \times 550H}{M}. \quad V = \sqrt{2gS}. \quad V = \sqrt{\frac{550 \times 3600gW}{M}}.$$

Time of duration in seconds.

$$T = \frac{2 \times 550H}{gM}. \quad T = \sqrt{\frac{2S}{g}}. \quad T = \sqrt{\frac{550 \times 3600 \times 2W}{gM}}.$$

Power in foot-pounds.

$$P = \frac{MTg}{2}. \quad P = \frac{MV}{2}. \quad P = \frac{M2S}{T}. \quad P = 550 \times 3600W\sqrt{\frac{g}{2S}}$$

Horse power.

$$H = \frac{MTg}{2 \times 550}. \quad H = \frac{M\sqrt{2gS}}{2 \times 250}. \quad H = \frac{MV}{2 \times 250}. \quad H = \frac{3600W}{T}.$$

Work, in workmandays.

$$W = \frac{MV^2}{g550 \times 3600}. \quad W = \frac{MS}{550 \times 3600}. \quad W = \frac{P\sqrt{\frac{2S}{g}}}{550 \times 3600}. \quad W = \frac{H\sqrt{\frac{2S}{g}}}{3600}.$$

Number of laborers (not workmandays), $L = \frac{MSn}{550 \times 3600D}$.

Working days of 11 hours each, $D = \frac{MSn}{550 \times 3600L}$.

Number of horses, (not horse power), $N = \frac{MSn}{11 \times 550 \times 3600D}$

Work in workmandays, $W = \frac{MSn}{550 \times 3600}$.

Examples for Work under the action of Gravity.

EXAMPLE 9. A steam-hammer weighing $M = 13450$ lbs falls from a height of $S = 7$ feet. Required how much work the hammer can do in each blow?

2d. formula for work.

$$W = \frac{MS}{550 \times 3600} = \frac{13450 \times 7}{550 \times 3600} = 0{\cdot}04755 \text{ workmandays,}$$

and $0{\cdot}04755 \times 11 = 0{\cdot}523$ hour.

That is, one man working 0·523 of an hour can accomplish the same work as that of each blow of the steam-hammer. The horse power of the hammer in its fall is found by the second formula, but this is not the horse power acting on the mass of iron to be forged on the anvil. If we know the time from when the hammer first touched the iron until it stops, then the horse power could be found by the fourth formula. The cooler the iron is, and the more resistance presented to the blow, the greater will the horse power be; but the correct measure of the capacity of a hammer is the workmandays, or its weight multiplied by the height of its fall.

EXAMPLE 10. A steam-hammer of $M = 10000$ lbs falling a height of $S = 4$ feet. Required the average horse power acting in the fall?

2d. formula for horse power.

$$H = \frac{W\sqrt{2gS}}{2 \times 550} = \frac{10000 \times \sqrt{2 \times 32{\cdot}16 \times 4}}{2 \times 550} = 164 \text{ horses.}$$

EXAMPLE 11. From what height $S = ?$ must a mass $M = 31800$ lbs fall to accumulate a work of $W = 3{\cdot}6$ workmandays.

4th. formula for space.

$$S = \frac{550 \times 3600\, W}{M} = \frac{550 \times 3600 \times 3{\cdot}6}{31800} = 224{\cdot}15 \text{ feet.}$$

EXAMPLE 12. How much work is accumulated in a mass of $M = 26800$ lbs and with a velocity of $V = 60$ feet per second?

1st. formula for work.

$$W = \frac{MV^2}{g\ 550 \times 3600} = \frac{26800 \times 60^2}{32{\cdot}166 \times 550 \times 3600} = 1{\cdot}515 \text{ workmandays.}$$

or it would require one man to work $1{\cdot}515 \times 11 = 16{\cdot}66$ hours, to wind up the mass M so high that it would in its fall attain the velocity V.

EXAMPLE 13. Required how high $S = ?$ the mass M in the preceding example, must be raised, in order to attain a velocity of $V = 60$ feet per second in its fall?

3d. formula for space.

$$S = \frac{V^2}{2g} = \frac{60^2}{2 \times 32{\cdot}166} = 55{\cdot}96 \text{ feet the answer.}$$

EXAMPLE 14. What mass $M = ?$ can be raised up $S = 68$ feet by $W = 16$ workmandays.

2d. formula for mass.

$$\text{M} = \frac{550 \times 3600 \text{w}}{\text{s}} = \frac{550 \times 3600 \times 16}{68} = 465882 \text{ pounds.}$$

EXAMPLE 15. How much work is required to raise M = 3137800 pounds, to a height of S = 80 feet.

2d. formula for work.

$$\text{W} = \frac{\text{MS}}{550 \times 3600} = \frac{3137800 \times 80}{550 \times 3600} = 12{\cdot}678 \text{ workmandays.}$$

EXAMPLE 16. How many laborers are required to do the work W = 12·678, in D = 3 days.

$$\text{L} = \frac{12{\cdot}678}{3} = 4{\cdot}226 \text{ laborers.}$$

EXAMPLE 17. How many laborers L = ? are required to strike $n = 1000$ blows in D = $\frac{1}{2}$ or half-a-day with a pile-driver? the ram weighing M = 2000 lbs. and lifted S = 1·5 feet in each blow.

$$\text{L} = \frac{\text{M S } n}{550 \times 3600 \times 0{\cdot}5} = \frac{2000 \times 1{\cdot}5 \times 1000}{550 \times 3600 \times 0{\cdot}5} = 3 \text{ men.}$$

EXAMPLE 18. How many days are required for N = 2 horses to draw up from a mine M = 18948000 lbs. of coal? the depth of the mine is S = 250 feet.

$$\text{D} = \frac{\text{M S}}{550 \times 3600 \times 11\text{N}} = \frac{18948000 \times 250}{550 \times 3600 \times \text{H}2} = 47{\cdot}295 \text{ days.}$$

To be continued on physical work by the combined action of the force of gravity and mechanical force; also on physical work generated by the action of heat.

Proceedings of the Association for the Prevention of Steam Boiler Explosions, Manchester.

From the London Mechanics' Magazine, April, 1864.

[Report of Chief Engineer, *April 26, 1864.]

During the last month 199 engines have been examined, and 313 boilers, 8 of the latter being examined specially, and 1 of them tested with hydraulic pressure. Of the boiler examinations, 253 have been external, 9 internal, and 51 thorough. In the boilers examined, 140 defects have been discovered, 7 of them being dangerous. Of some of these defects, a few further particulars may be given, not that there is anything very novel about them, but because it is just those practical defects that are of common occurrence which it is important—and the more so on account of their very frequency—to note and avoid. It is thought, therefore, that a statement of the defects constantly met with in the boilers inspected will be of service, not to the steam user only, but also to the boiler setter and maker. Four dangerous cases of fracture all occurred at the seams of rivets at the bottom of

*Error page 246—for "May 2," read "April 5."

externally fired boilers, as well as six others, which were serious though not actually dangerous. In three of these cases the injury manifested itself in leakage, and in cracks at the rivet holes, some of them extending for as much as 12 inches into the plate. In the fourth instance, one of the plates over the fire rent completely through from one end to the other, at a transverse line of rivet holes, the rent gaping open about $\frac{3}{4}$ of an inch. In this instance the boiler was nearly new, having only been laid down about six months, and had not been severely pressed during that time, while the character of the workmanship was good. The feed water, however, was introduced at the furnace end of the boiler, and too near to the plates over the fire, while it was of a sedimentary character; and though it did not form a tenacious scale, deposited a good deal of powder, which was so fine as to be almost impalpable; in addition to which, the boiler was not fitted with any blow-out apparatus. It is to these causes that the failure is attributed, although it should be added that the feed was heated before its introduction to the boiler by the exhaust steam from the engine. From the fact of the boiler being new, the workmanship good, the service was not very severe, and the feed water heated, it might have been supposed that, if any externally-fired boiler could escape fracture, this one would have done so, and its failure affords another illustration of the necessity, so frequently pointed out in previous reports, of introducing the feed to these externally-fired boilers, by means of a horizontal perforated pipe at a distance from the furnace, and also of adopting an efficient blow-out apparatus for the prevention of deposit. There is little question that these precautions would have prevented the injury in the present instance. A boiler lately put under the charge of the Association was found on the first "Thorough" examination to be so eaten away at the bottom over the mid-feather wall, on which it was set that a considerable portion of the plates were reduced to half of their original thickness; fortunately the diameter of the boiler was small, so that there was a considerable margin of strength. It is, however, another of those constantly recurring instances of the danger of setting boilers on mid-feathers.

One instance of dangerous grooving occurred to a multitubular boiler, and at the transverse seams at the bottom, the plates being so seriously reduced in thickness that the inspector made two or three holes through them at the time of his examination. It should be stated that this boiler had external brick flues, which had been supplemented since it was originally laid down. Instances of external grooving similar to the above are of very frequent occurrence in multitubular boilers, owing to the straining of the seams of rivets at the bottom, which is induced by the various temperatures of different parts in consequence of the imperfect circulation of the water; while it may be added that three other cases have been met with during the past month which, though not at present actually dangerous were still serious, and the corrosion steadily progressing.

Two Butterley boilers, put under the charge of the Association during the last month, were found to have been worked with steam

at as high a pressure as 40 lbs, although they were 8 feet in diameter, made of plates three-eighths of an inch in thickness, and 15 years old.

One case of deficiency of water occurred during the night time to an internally-fired boiler, which was one of a series connected together, and under the charge of the watchman, who though firing-up to raise steam so as to be ready for starting by six o'clock, appears to have been perfectly oblivious to the fact of their being no water in the gauge glass. The two fusible plugs, however, with which the boiler was fitted, both acted, and thus saved the furnace crowns from injury. The water had been lost in the following way:—All the steam junction valves were screwed down, and the pressure of steam in the boiler in question happened to be higher than that in the adjoining one, and thus the water had been driven from one into the other. This would not have been possible, even in spite of the inequality of steam pressure, had the feed back pressure valves been rightly constructed. But the valve and the spindle were not detached, but linked together by a collar at the end of the latter, so that although the valve was self-acting within a certain range, one turn of the screw beyond that point held it off from the face, and rendered it no longer a self-acting feed back-pressure valve; and hence the loss of water just referred to. The danger of such a mode of construction will at once be seen, and the importance of having the valve and spindle *entirely distinct* one from the other, and *not linked together in any way*. It is recommended that all those members whose valves are of similar construction to the one which permitted the loss of water referred to above, should have them remedied at once.

An explosion took place on the 2d of February last, of which the particulars could not be obtained at the time. The engineer has been supplied with a copy of the report drawn up by the two engineers appointed to examine the boiler and to investigate the cause of the explosion, the report being accompanied with a drawing showing the construction of the boiler, as well as the position and character of the rents. From these sources of information the following particulars have been taken:—It appears that the boiler was of Cornish construction, and internally-fired, having one furnace tube, which was of oval shape. The shell was 26 ft. in length, and 6 ft. in diameter, while the oval flue was 3 ft. 10 ins. width, and 3 ft. 4 ins. in height. The oval shape of this flue necessarily made it very weak, more especially so, since the major axis was horizontal, and the crown consequently flat. Were internal furnace-tubes subjected to statical pressure only, it would be immaterial whether the major axis in those of oval shape were horizontal or vertical, but in consequence of the columnar action which is induced by the expansion of the plates by the action of the fire, and which especially affects the upper part of the tubes, the conditions become altogether altered, and those tubes that have flattened crowns are particularly liable to collapse. On account of its oval shape this tube had been stayed with cast iron flanged pipes placed within it, which acted as pillars or struts in resisting the external pressure.

These pipes were spaced at irregular distances, set vertically and fixed from the inside of the tube. The boiler is reported to have been fitted with a Bourdon steam-pressure gauge, also suitable water gauges and an adequate safety-valve, loaded to 22 lbs on the square inch. The flue collapsed at about the middle of its length, and rent at the crown through one of the transverse seams of rivets, the plates being forced down till they touched the bottom of the flue; while, in addition, the upper half of the furnace mouth angle iron had rent from the front plate. Also two of the cast iron pillars had been dislodged, one of them being found after the explosion lying within the flue near the rupture, and the other a few yards in front of the boiler, a piece being burnt off the end of it, while the pillar was evidently too short for the purpose for which it had been intended. The preceding statement of facts will leave no room to doubt, that the cause of the explosion was simply the insufficiency of the boiler, especially when it is added that old cracks about 5 feet long, were found running along the sides of the flue, and which had been patched with plates barely one-quarter of an inch in thickness. The boiler was evidently malconstructed in the first place, and its condition neglected in the second, and hence the explosion, which competent inspection could not have failed to prevent. For the past month one explosion is reported, by which one man was killed and three others injured. It occurred at a considerable distance from Manchester, and consequently has not been personally investigated. The boiler in question, which was of marine construction, was not under the inspection of the Association.

—

[Report of the Chief Engineer, May 31, 1864.]

During the last month 226 engines have been examined, and 402 boilers, 16 of the latter being examined specially, and 1 of them tested with hydraulic pressure. Of the boiler examinations, 287 have been external, 18 internal, and 97 thorough. The following defects have been found in the boilers examined:—Furnaces out of shape, 2 (1 dangerous); fracture, 8 (2 dangerous); blistered plates, 2; internal corrosion, 11; external corrosion, 9 (3 dangerous); internal grooving, 8; external grooving, 4; feed apparatus out of order, 1; water gauges ditto, 9 (1 dangerous); blow-out apparatus ditto, 9; fusible plugs ditto, 2; safety-valves ditto, 1; pressure gauges ditto, 11; deficiency of water, 1; total, 78 (7 dangerous). Boilers without glass water gauges, 5; without pressure gauges, 2; without blow-out apparatus, 22; without back pressure valves, 22.

Six explosions occurred during the past month, by which 11 persons have been killed, and 13 others injured. None of the boilers were under the inspection of this Association, while all of them, with one exception, have been personally examined since the explosion. One of these, by which one person was killed and two others injured, occurred to the boiler of a locomotive engine, while standing at a short distance from a railway station. The locomotive, which was employed on goods traffic, and had six wheels coupled, was of the ordi-

nary construction, and about 10 years old, having been re-tubed two years since. The cylindrical portion of the boiler, as well as the crown of the outer fire-box shell, was rent into a number of pieces; and but little of the portion of the boiler shell between the fire-box and the smoke-box left; while many of the tubes were fractured, and the remainder bowed outwards. The fragments were scattered in every direction, and some of them blown to a great distance, one of the spring balances belonging to the safety-valves falling through the roof of a cottage, and seriously injuring one of the inmates. The cause of the explosion was attributed at the inquest by three successive witnesses, all of whom were practical boiler-makers, to shortness of water and consequent overheating of the plates. This, it was thought had produced a gas inside the boiler, which, upon ignition from the hot tubes caused the explosion. For this, it was added, the driver, who had been killed by the explosion, was responsible, in having allowed shortness of water to occur. The jury brought in a verdict of accidental death, adding, that they could not clearly ascertain the reason of the explosion. A personal examination of the exploded boiler led to a very different conclusion from that given in the preceding evidence. The crown of the inner fire-box, as well as its sides, was found uninjured, and the roofing stays in perfect condition; while the rents, instead of being in the fire-box, which would have been the case had the plates been overheated, were confined to the external shell, as already described; so that it is clear that the explosion was not due to shortness of water. On further examination, it was found that the character of the water was somewhat corrosive, and the surfaces of some of the plates had been eaten into indentations by it; while close to the overlap at a longitudinal seam of rivets, at the left hand side of the cylindrical portion of the boiler, and in the ring of plates nearest to the smoke-box, a deep furrow was found to have been eaten, which ran longitudinally more than half-way across the width of the plate. At this furrow, which was about the water-line, the plate had rent, and there can be but little question that this rent was the primary one from which the other developed, and to which the explosion had been due; so that the supposition of shortness of water, as well as that of the formation of explosive gases, and the neglect of the engine driver, may be dismissed, and the explosion attributed simply to weakening of the plates through the furrowing action, which is found to be more or less developed in nearly all boilers, but more especially in locomotives.

The next, like the preceding one, occurred to the boiler of a locomotive engine, while standing very near to the station. The locomotive was employed on passenger traffic, was of the ordinary construction, and about ten years old. The shell rent at the base of the steam dome, which was shot upwards, and thrown to a considerable distance. From this opening a number of rents radiated, and the upper part of the cylindrical portion of the shell was rent into several pieces, which, however, did not fly to any great distance, and but little damage resulted from the explosion altogether. The consideration of the di-

rections in which the fragments had flown, as well as an examination of the parts themselves, left little room to question that the primary rent had occurred at the base of the steam dome, where the ring of angle iron, with which it was attached to the shell, was found to be severed for a considerable distance through the line of rivet-holes. This explosion is considered, therefore, to have been due to the existence of the steam dome, and that, had it not been for this, the explosion would not have occurred. The danger of these steam domes has been frequently pointed out to the members of the Association; and this explosion, which is by no means singular, affords an additional illustration of the importance of dispensing with them altogether, at all events, in stationary boilers. A good deal of misconception, however, exists with regard to their efficiency; and they are considered by some to make a valuable addition to the amount of steam room within the boiler, and thus to compensate for irregular loads upon the engine. The fallacy of this, however, may be simply shown. Few steam domes exceed by more than four times the capacity of the engine cylinder, so that, even if the dome could be entirely exhausted, it would work the engine but a few strokes; while the entire space above the water line in a Lancashire boiler, 7 ft. in diameter and 30 ft. long contains but little more steam than the amount generated every minute when in ordinary work. Again, one foot of chamber room, filled with steam at 60 lbs, will only yield 4 ft. at atmospheric pressure; whereas, 1 cubic foot of the water, which would be of a temperature of 309°, Fahr., would yield considerably above 100 cubic feet of steam at atmospheric pressure. So that in a boiler worked at a pressure of 60 lbs a foot of space, filled with water, has stored up within it more than thirty times as much power as one filled with steam. From this it will be clear that the reservoir of power is not in the steam, but in the water. In order to prevent priming, all that is necessary is to take the steam off at a number of points, and not to allow a concentrated rush at any one. To effect this, horizontal perforated pipes, carried along within the steam space, which are so widely known, are found to be most efficacious. A considerable number are at work in the boilers under inspection and give very satisfactory results.

—

[Report of the Chief Engineer, June 28, 1864.]

During the last month 272 engines have been examined, and 419 boilers, 22 of the latter being examined specially, and one of them tested with hydraulic pressure. Of the boiler examinations, 364 have been external, 8 internal, and 47 thorough. In the boilers examined, 154 defects have been discovered, 2 of them being dangerous.

The particulars of the explosions, which were postponed from the last monthly report, may now be given. None of the boilers in question were under the inspection of this Association; while they have all been personally examined since their explosion, and the cause of the occurrence investigated. No. 12 explosion resulting in the death of one person, and in serious injury to another, occurred at an iron-

works to a plain cylindrical egg-ended boiler, fired externally, and not under the inspection of this Association.

The boiler was one of a series of five connected together and working side by side, being No. 4 from the left hand. Its length was 40 ft., its diameter 6 ft., and the thickness of the plates $\frac{3}{8}$ of an inch.; while the pressure of the steam was 35 lbs, which was quite moderate for a boiler of such dimensions. It had rent into eleven fragments, which were scattered in every direction, one of them being thrown to a distance of 200 yards. The character of these rents was peculiar. The majority of boilers of this class divide into two parts at one of the transverse seams of rivets, but this one had not only rent transversely, but also longitudinally, from one end to the other, so as to divide the boiler in the main into four nearly equal parts; while these were again subdivided, and the shell ultimately broken up into the eleven pieces just named. These rents were by no means confined to the lines of rivets, but had run through the solid plates entirely regardless of them, in many cases continuing for several feet within a few inches of the overlaps, and though so near, yet without running into them, but continuing in a straight line parallel to them. Indeed, there was scarcely a line of rivets disturbed, and some of the smaller fragments were torn out of the heart of the larger plates without a single rivet upon them.

The boiler had been originally plated longitudinally, but on the seams over the fire giving way some time since, it had been repaired with three widths of plate laid transversely. These plates, which were 3 ft. wide each, extended to a short distance behind the fire bridge, and it was at the ring seam of rivets that connected the new plating laid transversely, with the old laid longitudinally, that the primary rent occurred, and which it will be seen was situated, as is so usual in these cases, near to the bridge, and at the bottom of the boiler; while the anomalous manner in which the boiler had rent was due to the combination of the transverse and longitudinal modes of plating. The manager of the works informed me that their externally-fired boilers were a source of constant annoyance and expense, through getting out of repair, and it was no uncommon thing for one of the ring seams, a little behind the fire bridge, suddenly to rend through the line of rivet holes, merely in consequence of the slight change of temperature induced on the stoker's cleaning out the fires with the door open. The fact of these externally-fired boilers being ever found to give way in this treacherous manner, seems to me a sufficient reason to condemn them, especially at iron-works where the value of the charge of metal in the blast furnaces, which far exceeds that of the boilers, is jeopardized by them. That the remaining boilers in the series, or the furnaces themselves, escaped in this instance, is a piece of peculiar good fortune, since, in other cases, the whole range of boilers has been instantaneously destroyed, and the blast furnaces themselves demolished.

No. 13 Explosion took place at a colliery. In this instance three

persons were killed, and three others injured; while the boiler, which was not under the inspection of this Association, was the outer one of a series of three, and, as in the case of the previous explosion, was of plain cylindrical egg-ended construction, and externally-fired. The boiler, which was plated longitudinally throughout, was 32 ft. long, 6 ft. 6 ins. in diameter, and made of plates $\frac{3}{8}$ of an inch in thickness, the pressure of steam being 35 lbs per square inch. The primary rent occurred at a longitudinal seam of rivets over the fire, which after running in a straight line for some feet developed transversely, dividing the shell into three fragments, all of which were thrown to a considerable distance from their original seating; while in addition, the adjoining boiler was dislodged, and turned up on end by the force of the explosion. When it is stated that the plates at the fractured part proved to be very defective, and also that this boiler had leaked for some time at the seams over the fire, so that the introduction of bran had been resorted to in order to stop it, it will not be necessary, after what has been said on the danger of these externally-fired boilers, to add anything further to account for this explosion; while it will appear that these boilers, whether plated longitudinally, as in the present instance, or transversely, as according to the more usual practice, are alike prone to explosion.

No. 15 Explosion by which one man was killed, was due to the collapse of the combustion chamber of a boiler of the double furnace or breeches class, working at a flour-mill, and which was not under the inspection of this Association.

The boiler was a left hand one of a series of three, the shell being 7 ft. in diameter, and 26 ft. 6 ins. long; while the diameter of the furnaces was 2 ft. 9 ins., and that of the flue 3 ft. 3 ins.; the length of the combustion chamber being 4 ft. 6 ins.; the thickness of the plates $\frac{3}{8}$ of an inch, and the steam pressure 45 lbs. The boiler had been built by a first-class maker, and the quality of the material as well as the character of the workmanship appeared to be good throughout.

The rush of steam and water from the rent in the combustion chamber drove the boiler about 6 ft. forward into the firing space, and although the other boilers remained unmoved, yet the steam pipe connexions to them were broken. In consequence of this, the steam and hot water escaping from the junction valve on the centre boiler, played with fatal effect into the firing space and engine room. The engineer and stoker, who were there at the time, made a rush at the first sound of the collapse, to a door which opened out on the river running directly alongside of the boiler-house, and the tide being out, jumped down upon the bed. The engine-man happily escaped with a few bruises, but the stoker, less fortunate, was so severely scalded that he died the same night. The collapse of the combustion chamber had taken place, not at the crown but at the underside, and this arose from the fact that while the crown was stiffened with roofing stays, assisted by tie rods connected to the shell of the boiler, the bottom of the combustion chamber was comparatively unstayed, having but a single angle iron running longitudinally on the centre line, in addition to a

small gusset on each side. These breeches or combustion chambers have already proved a very fruitful source of explosion, and it is important that any steam users, who are employing boilers of this construction, should have these chambers stayed with vertical water tubes which act as internal columns or struts, and thus prevent the top and bottom plates of the chamber coming together; while, in addition, it is frequently if not always desirable, that the flue should be encircled with an angle iron hoop just at the waist or termination of the breeches piece. In some cases, where the pressure is low, this hoop of itself would be sufficient, and under many circumstances would perhaps be more easily obtained than the water tubes. Had these precautions been adopted in the boiler under consideration, the collapse of the breeches or combustion chamber, and the consequent explosion, would have been prevented.

Sir John Herschel on the French and English Standards of Measurement.

From the Lond. Civil Eng. and Arch. Jour., July, 1864.

We extract the following letter to the editor from a recent number of the *Times:*

In the *Times* of Thursday, the 16th inst., I observe a letter addressed by Mr. Ewart to the editor of the *Journal des Debats* on the subject of the introduction into this country of the French metrical system. In this letter Mr. Ewart appears to be at a loss to understand why the *Times* has all along raised its voice in opposition to the proposed change; and speaks of the prevalent repugnance to its adoption as arising merely from British prejudice, which he considers to be gradually yielding to the efforts making by himself and his coadjutors to enlighten us as to its advantage.

It is well for those who have adopted a contrary opinion, whether from the exercise of their own judgment, or from a perusal of the many able expositions of the confusion and inconvenience the change would create which have from time to time appeared in your columns, to be enabled to render an account of the faith that is in them; and you will excuse me if I observe that, in the articles referred to, I nowhere find any clear and distinct statement of those reasons which appear to myself decisive against the change on purely scientific grounds, and which lead me to regard it, scientifically considered, as a retrograde step. These, with your permission, I will endeavor to state as briefly as may be, for the benefit of that very large portion of the public who may not have read my recent remarks on the subject in one of our most widely circulated monthly periodicals.

Whatever be the historical origin of our standards of weight, capacity, and length, as a matter of fact our British system refers itself with quite as much arithmetical simplicity, through the medium of the inch, to the length of the earth's polar axis (a unit common to all nations) as the French does through that of the metre to the elliptic quadrant of a meridian passing through Paris (a unit peculiar to France). It does so as regards our actual legal standards of weight and capacity

with much more precision than the French system, and as regards that of length (with a correction which, if legalized, would be absolutely imperceptible, from the smallness of its amount, in any transaction of life, and which can be applied, *currente calamo*, almost without calculation to any statement of lengths) with even still greater, and indeed with all but mathematical, exactness.

If the earth's polar axis be conceived divided into five hundred million inches, and a foot to be taken to consist of 12 such inches, then one hundred of our actual legal imperial half-pints by measure, or one thousand of our actual imperial ounces by weight, of distilled water at our actual standard temperature of 62° Fahr., will fill a hollow cube having one such foot as its side. The amount of error in either case is only one part in 8000.

The theoretical French metre is one ten-millionth part of the elliptic quadrant above mentioned; the theoretical litre is one-thousandth of a cubic metre; and the theoretical gramme, one millionth part of a cubic metre of distilled water at 32° Fahr. The actual error of the French legal or standard litre or gramme, or the deviation of these standards as they actually exist, from their true theoretical value, is one part in two thousand seven hundred and thirty (2730), and is consequently relatively nearly three times as great as the error in our standards of capacity and weight when referred to the earth's polar axis as their theoretical origin in the manner above stated.

Our actual imperial measures of length deviate, it is true, by more than this amount from their theoretical values so defined; that is to say, by one part in one thousand; so that a correction of one exact thousandth part subtracted from the stated amount of any length in imperial measures suffices to reduce it to its equivalent in such units as correspond to similar aliquots of the polar axis; a correction performed if needed, as already remarked, *instanter*, and *currente calamo* requiring no tables and almost no calculation. So corrected the outstanding error is only one part in sixty-four thousand (64,000). The actual legal metre in use in France is however, not immaculate in this respect, its amount of error being one part in six thousand four hundred (6400), which is ten times that which our British measures so corrected would exhibit.

If it were worth while to legalize so trifling an alteration (and were an Act passed rendering permissive the decimalization of our own system, it would be necessary to do so as a means of bringing the national units of length, weight, and capacity, into exact decimal correspondence), no mortal would be aware, practically speaking, that any change had been made in our mile, yard, foot, or inch. I have in common use two foot rules bought at respectable shops, and neither the worse for wear, which differ by more than the amount of change required.

The writer in the *Journal des Debats* is pleased to say that England stands in extensive commercial relations with only one considerable nation (North America) employing the British system of weights and measures. British commerce extends, however, to Russia, British India

and Australia, all of them superior in area, and the two last, at least, of equal importance, commercially speaking, with the totality of the metricised nations. The Russian sagene is an exact multiple of the English foot (imperial). The hath (the legal measure of length in British India) is 18 imperial inches. The Australian system is identical with our own. Taking into consideration this immense preponderance, both in area, in population, and in commerce, we are not only justified in taking our stand against this innovation, but entitled to inquire, if uniformity be insisted on, why, with an equally good theoretical basis (to say the least), the majority is called upon to give way to the minority.

J. F. W. HERSCHEL.

Collingwood, June 18.

For the Journal of the Franklin Institute.

Atmospheric Pressure as a Traveling Force, versus *Animal Power and Steam Locomotives.*

(Continued from page 279.)

It may readily be supposed that to establish Pneumatic passenger lines, the dimensions of the tunnels or tubes should be as small as possible, not only because their cost swells greatly with their bore, but because the larger one is the larger are the volumes of air to be drawn out, and the longer the time and greater the outlay of force to do that. This may be said to depend on the arrangement of the passengers seats. In common cars it matters little how they are placed, in the direction of the length or breadth of the cars, but in an air tube the difference is very great. Every addition to its width enlarges its capacity and cost. A company of soldiers can march in single file through a passage less than three feet wide, but not in squads of three or four abreast; so a pneumatic tunnel adapted for a single row of passengers can pass the same number through as a much larger one seated across it, and in the same time. If length be thus substituted for breadth, the result would be a tube, the cost of which would be reduced to a minimum, and, as it would seem, the expense of working it also.

What then is the form and size of such a tube? We assume that one whose section is a circle five feet in diameter could receive two rows of passengers seated *vis à vis* as in fig. 1, with the space under the seats excluded. The sitting posture would be uneasy for tall travelers and there would be a lack of head-room on going in and out. This would suggest the drawing in of the sides so as to form an ellipse by dividing of which vertically and taking half of it, we should have, with a slight modification, the second figure. But though here taken for a section of a tube of the smallest dimensions it can only be considered as that of the car, to which the tube proportionately enlarged would have to conform.

It is, however, obvious that so severe an economy of space and such a disposition of travelers would militate against, if they did not prove fatal to the system. The comforts and conveniences of travel would be materially lessened, social and confidential converse, except with

adjoining individuals, would be out of the question, while almost every one would be cramped for want of room and change of position. Traveling in a single file cannot become a general feature of atmospheric lines, nor is it so essential in an economical point of view, as has just been supposed. The reasoning in the first paragraph is plausible and would be conclusive if a liquid instead of air had to be pumped out. It is to some extent superficial. Almost as much may be advanced in favor of the proposition that in the working of a line little is gained by a small tube over a large one.

Imagine two laid down of equal length, one having a sectional area twice that of the other, equal loads linked to the pistons, and each operated on by a like amount of exhausting power: would not the trains start together and reach the end of the routes at the same time, and with the same expenditure of force? While the larger one had a double quantity of air to remove, its density would only require to be half diminished. If the smaller piston had a pressure of 8 lbs. on the inch, that of the other would have 4 lbs. on an area twice as large. So that, throwing friction of the pistons out of view, as regards speed and power, they would be much alike, and accommodations in common cars are compatible with Pneumatic tunnels of moderate dimensions.

The principle by which the resistance is accommodated to the force and the force to the resistance, is one of the fluid phases of the lever. Its applications may be supposed in their infancy, and this pumping of men and merchandise, like water, through pipes, a foreshadowing of its future operations. E.

Protecting Armor Plating.

From the London Artizan, Sept. 1864.

Great success has attended the plan adopted for protecting the armor plating of the iron-cased wooden frigates, as applied in the first instance of the ***Royal Oak***. This vessel has been admitted into the dock at Malta for the purpose of ascertaining the results of the measures adopted for preventing the effects of galvanic action on the armor plating. The plan, which was suggested by Mr. Reed, the chief constructor of the navy, consists in sheathing the plates with teak planking three inches in thickness, the inside of the planking and the surface of the armor plating being at the same time coated with Hay's water-proof glue, and the planking attached to the armor plates by short screws. Since the *Royal Oak* has been in dock at Malta a portion of the planking has been removed, and the results have been in the highest degree satisfactory, the armor plates having been perfectly protected, while not even the slightest trace of galvanic action can be detected. This improvement in the way of preserving the armor plating of wooden frigates is the more important when it is recollected

how seriously the plates of the *Royal Oak* were found to have suffered only a very short time after the frigate had been launched, on the vessel being docked and inspected in this country. Mr. Reed's plan was subsequently applied to the *Ocean*, armor-cased frigate, at Devonport, and so satisfied are the Lords of the Admiralty with the results in the case of the *Royal Oak*, that they have ordered the whole surface of the armor below the water to be protected in the same way and the work will be carried out at Malta dock-yard.

For the Journal of the Franklin Institute.

Strength of Cast Iron and Timber Pillars: A series of Tables showing the Breaking Weight of Cast Iron, Dantzic Oak, and Red Deal Pillars. By Wm. Bryson, Civ. Eng.

(Continued from Vol. xlv., p. 186.)

Solid Uniform Square Pillars of Dantzic Oak, both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Side of the square in inches.	Value of w in tons from formula $w = 10{\cdot}95\frac{d^4}{l^2}$	Value of c.	Calculated breaking weight in tons from formula. $Y = \frac{wc}{w+\frac{1}{4}c}$
8	6·2036	253·40	132·8	95·33
10	"	162·17	"	82·27
12	"	112·62	"	70·47
14	"	82·74	"	60·26
16	"	63·35	"	51·62
18	"	50·05	"	44·41
20	"	40·54	"	38·41
22	"	33·50	"	33·42
8	8·8622	1055·39	271·04	227·26
10	"	675·45	"	208·33
12	"	469·06	"	189·09
14	"	344·61	"	170·47
16	"	263·84	"	153·08
18	"	208·47	"	137·22
20	"	168·86	"	122·98
22	"	139·55	"	110·32
24	"	117·26	"	99·15
26	"	99·91	"	89·31
28	"	86·14	"	80·66
30	"	75·05	"	73·08

Solid Uniform Square Pillars of Red Deal, both Ends being Flat and Firmly Fixed.

		$w = 7{\cdot}81\frac{d^4}{l^2}$		
8	6·5	217·83	124·21	87·00
10	"	139·41	"	74·45
12	"	96·81	"	63·30
14	"	71·12	"	53·77
16	"	54·45	"	45·82
18	"	43·02	"	39·24
20	"	34·85	"	33·81

Hollow Uniform Cylindrical Pillars of Cast Iron, both Ends being Rounded or Irregularly Fixed.

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formula $W = 13\frac{D^{3\cdot76} - d^{3\cdot76}}{L^{1\cdot7}}$	Value of w.	Value of c.	Calculated breaking weight in tons from formula. $Y = \frac{wc}{w + \frac{3}{4}c}$	Strength per sq. inch of section in tons.
1	2	1·5	6		116·40	67·34	46·96	34·16
1·25			7·5		79·65	"	41·21	
1·5			9		58·42	"	36·12	
1·75			10·5		44·95	"	31·71	
2			12		35·82	"	27·94	20·32
2·25			13·5		29·32	"	24·73	
2·5			15		24·51	"	22·00	
2·75			16·5		20·84	"	19·67	
3			18		17·98	"	17·68	12·86
3·25			19·5	15·69				
3·5			21	13·83				
3·75			22·5	12·30				
4			24	11·02				8·04
4·25			25·5	9·94				
4·5			27	9·02				
4·75			28·5	8·23				
5			30	7·54				5·48
5·25			31·5	6·94				
5·5			33	6·41				
5·75			34·5	5·95				
6			36	5·53				4·02
6·25			37·5	5·16				
6·5			39	4·83				
6.75			40·5	4·53				
7			42	4·25				3·10
7·25			43·5	4·01				
7·5			45	3·78				
7·75			46·5	3·58				
8			48	3·39				2·47
8·25			49·5	3·22				
8·5			51	3·06				
8·75			52·5	2·91				
9			54	2·77				2·01
9·25			55·5	2·65				
9·5			57	2·53				
9·75			58·5	2·42				
10			60	2·32				1·68
10·25			61·5	2·22				
10·5			63	2·13				
10·75			64·5	2·05				
11			66	1·97				1·43
11·25			67·5	1·90				
11·5			69	1·82				
11·75			70·5	1·76				
12			72	1·70				1·24

(Table continued.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formula $W = 13\frac{D^{3\cdot76} - d^{3\cdot76}}{L^{1\cdot7}}$	Value of w.	Value of c.	Calculated breaking weight in tons from formula. $Y = \frac{wc}{w + \frac{3}{4}c}$	Strength per sq. inch of section in tons.
1	2·5	2	4·8		230·85	86·59	67·57	38·24
1·25			6		157·97	"	61·45	
1·50			7·2		115·87	"	55·49	
1·75			8·4		89·16	"	50·09	
2			9·6		71.05	"	45·24	25·60
2·25			10·8		58·15	"	40·90	
2·5			12		48·62	"	37·07	
2·75			13·2		41·34	"	33·68	
3			14·4		35 66	"	30·69	17·36
3·25			15·6		31·12	"	28·05	
3·5			16·8		27·44	"	25·72	
3·75			18		24·40	"	23·65	
4			19·2		21·86	"	21·81	12·34
4·25			20·4	19·72				
4·5			21·6	17·90				
5·75			22·8	16·32				
5			24	14·96				8·46
5·25			25·2	13·77				
5·5			26·4	12·72				
5·75			27·6	11·80				
6			28·8	10·97				6·20
6·25			30	10·24				
6·5			31·2	9·58				
6·75			32·4	8·98				
7			33·6	8·44				4·77
7·25			34·8	7·95				
7·5			36	7·51				
7·75			37·2	7·10				
8			38·4	6·73				3·80
8·25			39·6	6·38				
8·5			40·8	6·07				
8·75			42	5·78				
9			43·2	5·50				3·12
9·25			44·4	5·25				
9·5			45·6	5·02				
9·75			46·8	4·80				
10			48	4·60				2·61
10·25			49·2	4·41				
10·5			50·4	4·23				
10·75			51·6	4·07				
11			52·8	3·91				2·22
11·25			54	3·77				
11·5			55·2	3·63				
11·75			56·4	3·50				
12			57·6	3·37				1·91

(Table continued.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formula $W = 13\frac{D^{3\cdot76} - d^{3\cdot76}}{L^{1\cdot7}}$	Value of w.	Value of c.	Calculated breaking weight in tons from formula. $Y = \frac{wc}{w + \frac{3}{4}c}$	Strength per sq. inch of section in tons.
1	3	2·5	4		401·98	105·83	88·37	40·93
1·25			5		275·08	"	82·13	38·40
1·5			6		201·76	"	75·95	35·17
1·75			7		155·25	"	70·02	32·43
2			8		123·72	"	64·47	29·86
2·25			9		101·27	"	59·33	27·48
2·5			10		84·66	"	54·62	25·29
2·75			11		72·00	"	50·33	23·31
3			12		62·10	"	46·45	21·60
3·25			13		54·20	"	42·94	19·88
3·5			14		47·78	"	39·76	18·41
3·75			15		42·49	"	36·90	17·09
4			16		38·08	"	34·31	15·89
4·25			17		34·35	"	31·96	14·80
4·5			18		31·17	"	29·84	13·82
4·75			19		28·43	"	27·91	12·92
5			20	26·05				12·06
5·25			21	23·98				
5·5			22	22·16				
5·75			23	20·54				
6			24	19·11				8·85
6·25			25	17.83				
6·5			26	16·68				
6·75			27	15·64				
7			28	14·70				6·80
7·25			29	13·85				
7·5			30	13·07				
7·75			31	12·37				
8			32	11·72				5·42
8·25			33	11·12				
8·5			34	10·57				
8·75			35	10·06				
9			36	9·59				4·44
9·25			37	9·15				
9·5			38	8·75				
9·75			39	8·37				
10			40	8·02				3·71
10·25			41	7·69				
10·5			42	7·38				
10·75			43	7·09				
11			44	6·82				3·15
11·25			45	6·56				
11·5			46	6·32				
11·75			47	6·09				
12			48	5·88				2·72

(Table continued.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formula $W = 13\,\frac{D^{3\cdot76} - d^{3\cdot76}}{L^{1\cdot7}}$	Value of w.	Value of e.	Calculated breaking weight in tons from formula $Y = \frac{we}{w + \frac{3}{4}e}$	Strength per sq. inch of section in tons.
1	3·5	3	3·428		635·34	125·07	108·98	42·73
1·25			4·285		434·78	"	102·87	40·34
1·5			5·142		318·90	"	96·64	37·89
1·75			6		245·38	"	90·48	35·48
2			6·857		195·55	"	84·52	33·14
2·25			7·714		160·06	"	78·85	30·92
2·5			8·571		133 81	"	73·52	28.83
2·75			9·428		113·80	"	68·55	26·88
3			10·285		98·15	"	63·95	25·07
3·25			11·142		85·66	"	59·69	23·40
3·5			12		75·54	"	55·79	21·87
3·75			12·857		67·16	"	52·18	20·46
4			13 714		60·18	"	48·88	19·16
4·25			14·571		54·29	"	45·85	17·98
4·5			15·428		49·26	"	43·06	16·88
4·75			16 285		44·93	"	40·50	15·88
5			17·142		41·18	"	38·15	14·96
5·25			18		37·90	"	35·99	14·11
5·5			18·857		35·02	"	34·00	13·33
5·75			19·714		32·47	"	32·16	12·61
6			20·571	30·21				11·84
6·25			21·428	28·18				
6·5			22·285	26·36				
6·75			23·142	24·72				
7			24	23·24				9·11
7·25			24·857	21·89				
7·5			25·714	20·67				
7·75			26·571	19·55				
8			27·428	18·52				7·26
8·25			28·285	17·58				
8·5			29·142	16·71				
8·75			30	15·90				
9			30·857	15·16				5·94
9·25			31·714	14·47				
9·5			32·571	13·83				
9·75			33·428	13·23				
10			34·285	12·67				4·96
10·25			35·142	12·15				
10·5			36	11·66				
10·75			36·857	11·21				
11			37·714	10·78				4·22
11·25			38·571	10·37				
11·5			39·428	9·99				
11·75			40·285	9·63				
12			41·142	9·29				3·64

(To be continued.)

For the Journal of the Franklin Institute.

Compressed Air and Gunpowder as Traveling Forces.

The first, though often proposed has never been adopted, and, as I think, for a sufficient reason. It is certainly desirable that rail cars on short routes should be worked if possible by a portable inorganic force, even at a somewhat greater cost than by draft animals. Could this be done with compressed air the achievement would be a great one. Besides leaving street pavements untouched and therefore incurring no expense for re-paving them, the capital invested in horses and stabling, feed and attendants, &c., would be transferred to a steam-compressing engine, at one or both ends of a line, and to motive machinery more lasting than living tissues and much cheaper to keep.

The future has many good things in store for us, and, possibly, this may be among them, for it does not appear to be within the compass of our present resources. Difficulties and dissatisfaction attending our city cars have suggested afresh the use of compressed air without a due consideration of what it is competent to do and what not. True, the reservoir or receiver of each car would be filled in a moment or two, either directly by the engine or from a common reservoir kept charged to the proper tension, but with this serious drawback, that, as there would be no sustaining means, as with steam boilers, to keep up the supply, the force within would diminish with every portion of the fluid drawn out. Every stroke of the piston acting on the wheels would lessen it, and not in a constant but a constantly increasing ratio. A car would not have one-third of the power it started with, to carry it over the latter half of its route.

Something better might be done than has perhaps been attempted or proposed:—the air should be in two separate receivers, one for the first half of the route, the other for the second. Three would be better than two. They should be kept at as low a temperature as circumstances permit while being charged. The cooler they are the more air they would take in. The introduction of fuel is surely to be avoided, but if a small quantity should offer a decided gain it would hardly be wise to reject it. For example: the motive fluid might be made to do something like double duty by discharging it from the working cylinder into a heated chamber, to act on a larger piston as in the caloric or common air engines, or by applying a moderate and moderately increasing heat to the receiver itself. In stopping to take in and let out passengers, cars waste entirely their momentum and strain the sinews of the horses to start again: the power thus lost might be saved by making an injecting air pump the drag instead of buffers on the wheels.

But with these additions the prospect of successfully employing air is not encouraging. There is another obstacle in the disproportionate dimensions of the receivers. Instead of being light and portable they would be the reverse. Suppose the engine of a car have a 4-inch cylinder with a 12-inch stroke—it could not well be less—its capacity

would be 150 cubic inches. Sixty strokes a minute would use up 5½ cubic feet in that time, and a 20 minutes route 109 feet. Now, a cylindrical receiver capable of withstanding the required pressure, say from 100 to 200 pounds on the inch—should not exceed 15 inches diameter. To contain the supply for 20 minutes it would have to be nearly 100 feet long; to work the engine half an hour 150 feet, and for a whole hour its dimensions would approach those of a car and be three or four times as heavy.

Perhaps this may be thought an exaggerated view; that the fluid ought not to be measured by the cylinder, like liquids drawn from hogsheads by the gallon, but that some credit should be given for expansion by cut offs, &c. To meet this it will be sufficient to observe that it has been calculated as operating on the piston with equal energy throughout and as being wholly used up.

Hence, so far from being, what many imagine it, a force that may be conveyed hither and thither in receptacles relatively no larger than soda fountains are to steam boilers, it is anything but that. Recourse must be had to explosive compounds for the only real portable force at present attainable. In these it is offered to us in the least of imaginable packages, and of startling intensities. Thus 12 grains of gunpowder exploded by Rumford in a ¼-inch cylinder drilled in wrought iron gave out a force, measured by a loaded valve on the open end, of 9·431 atmospheres. When the cavity was quite filled with 26 grains the force was calculated at 410·624 lbs., or 182 tons on the inch. Later experimentalists have reduced these wonderful statements. Robbins calculated the pressure of the gases generated by the explosion of powder at 1000 atmospheres, or somewhat less than 6½ tons on the inch. But Hutton doubled this and Dr. Gregory confirmed his results. Others have since run it up to 2500 atmospheres.

To whatever cause the discrepancies are to be ascribed, to variations in the quantities of the powder, its filling or only partly filling the exploding chamber, &c., there is enough in all conscience in the lowest estimates to lead mechanicians to inquire if this amazing agent, resistless as an exploding force may not be converted into a quiet and efficient working one. Hautefille, Huygens, and Papin attempted this in the seventeenth century, and many more in the succeeding and the present one. Numerous notices may be found in the Mechanical Journals, but I do not remember any particular description of the testing apparatus, or any definite item of results. Desirous of ascertaining if the force could be introduced as a substitute for animals in rail cars at a moderate cost, I consulted my friend, Mr. James Bogardus, whose mechanical knowledge and inventive resource have rarely if ever been surpassed. The apparatus adopted was designed by him. It is only necessary to refer to a part of it here.

Instead of receiving the explosive impulse on air, the most elastic and durably elastic of agents, as suggested in the Patent-Office Report of 1849, the piston driven by the powder compressed a steel spring formed by bending to and fro, a bar, 20 feet long, 2 inches wide, and

¼-inch thick, into a series of short turns. The compressing force was determined directly by a weight passing over a pulley and making additions to it as the compression proceeded along a finely graduated scale. There could, therefore, be little or no mistake made in the amount of force thus received and given out to the revolving mechanism. The cylinder, or gun, was 2 inches bore and 16½ inches long. The piston and rod were of one piece of metal, the latter 1½ inches square.

The experiments were interrupted by the death of Mr. Dornbach, killed while packing a case of gun cotton. We had tried *white* powder and preferring it, were waiting a further supply from him. The delay in resuming them is moreover due to the fact that the magic power ascribed to powder in the books, and mining and military engineering, vanishes in the workshop.

The power of a single horse is commonly estimated at 33,000 lbs. raised one foot per minute.

We found 10 grains of powder only raised 250 lbs. one foot, hence 132 such charges, or 1320 grains, were required to bring it up to horse power. A pound contains 7000 and they could hardly keep the engine going 5⅓ minutes. Eleven pounds and a half would be consumed in an hour, and that at 20 cents per pound would amount to over twenty-two dollars for a working day of ten hours.

It should however be understood that from the construction of the testing machine, a feeding channel and a small receptacle for the residuum were exposed to the explosive impulse; and though the small quantity of air they contained gave back by expansion the compression received, there is little doubt that the effect on the piston would have been greater if there had been no communication with these—that is, if the force had been solely and strictly concentrated on the end of the piston. It was not intended to give any statements respecting the experiments till they were concluded, but on closing the remarks on Compressed Air, the opportunity seemed appropriate for a brief reference to them. E.

New York, October 18, 1864.

A Colorless Varnish.

From the London Chemical News, No. 246.

At the time the process of varnish-making by Luning was laid before the Society of Arts, Mr. Field put in a claim, when both the processes and products were found to answer the intended purpose, and the claimants were awarded twenty guineas each. Mr. Field describes his process as follows:—Six ounces of shellac, coarsely powdered, are to be dissolved by gentle heat in a pint of spirits of wine; to this is to be added a bleaching liquor made by dissolving carbonate of potash, and then impregnating it with chlorine gas till the solution becomes slightly colored. Of this bleaching liquor add one or two ounces of the spirituous solution of lac, and stir the whole well together. Effervescence takes place. When this ceases add more of the bleaching

liquor, and thus proceed till the color of the mixture has become pale. A second bleaching liquor is now to be added, made by diluting muriatic acid with thrice its bulk of water, and dropping into it pulverized red lead till the last added portions do not become white. Of this acid bleaching liquor, small quantities at a time are to be added to the half-bleached lac solution, allowing the effervescence which takes place on each addition to cease before a fresh portion is poured in. This is to be continued until the lac now white separates from the liquor. The supernatant fluid is now to be poured away, the lac well washed in repeated waters, and finally wrung as dry as possible in a cloth. The lac obtained by the foregoing process is to be dissolved in a pint of alcohol, more or less, according to the required strength of the varnish; and, after standing for some time in a gentle heat, the clear liquor—which is the varnish—is to be poured off from the sediment. When the processes of Luning and Field came before the Society of Arts, the Editor of the *Franklin Journal** (Philadelphia) made known the process of Dr. Hare, in which he stated that "all the objects sought for were perfectly attained, and left nothing to desire, save on the score of economy." The following was Dr. Hare's process:—Dissolve in an iron kettle one part of pearl ash in about eight parts of water, add one part of seed or shellac, and heat the whole to ebullition. When the lac is dissolved, cool the solution, and impregnate it with chlorine till the lac is all precipitated. The precipitate is white, but its color is deepened by washing and consolidation. Dissolve in alcohol. Lac bleached by this process yields a varnish as free from color as any copal.—*British Journal of Photography.*

Preserving Timber from Decay.

From the London Builder, No. 1121.

Experiments by Mr. Crepin are recorded in the *Annales des Travaux Publics de Belgique*, in connexion with Baltic timber creosoted by Mr. John Bethell's process. In October, 1857, creosoted fir, which had been taken from wood prepared in the ordinary way for the State railway, beech prepared with sulphate of copper, and fir and beech not prepared in any way, were placed 6 ft. 3 ins. (1·90) above the water mark upon the piles of the east pier at Ostend. In the beginning of January, 1859, the pieces were taken down and inspected. It was found that the piece of fir unprepared was much perforated by the teredo; that the piece of beech unprepared was perforated from one end to the other, that the pieces prepared with sulphate of copper were all three eaten by the teredo; and that the three pieces of creosoted fir alone were intact, and without a trace of the teredo. Mr. Crepin concludes that he cannot too strongly recommend the use of creosoted fir wood in hydraulic engineering, in preference to oak; since, in addition to its being cheaper, there is no doubt of the creosoted fir lasting longer. The Government Public Works Department has adopted this process, and constructed part of the dyke, and the

* Journal of the Franklin Institute.

whole of the American foot passengers bridge, in the new works at Ostend, of creosoted red fir. A report of Mr. Moir, with respect to the piles and other timber, in the pier at Leith Harbor, creosoted by Mr. Bethell, is equally satisfactory.

Illumination of Lecture Rooms by Electric Light.

From the London Chemical News, No. 243.

The good and learned Abbé Moigno deserves the thanks of his numerous friends in this city for having introduced an innovation at his last lecture on the Progress of Science during the month, in the hall of the Societé d'Encouragement, which cannot fail to be adopted, in hot weather at least, by all *entrepreneurs* of public meetings or entertainments. Instead of being illuminated by the innumerable jets of gas with which the hall is provided, a single electric light, placed in a central position, lit the room in the most perfect manner. The consequence was that, although the thermometer was above 100° out of doors, no one was inconvenienced by the heat, and although there were nearly 500 persons present, hardly a single pocket handkerchief was used as a *sudarium* during the meeting. While enjoying the comparative coolness, one could not help thinking of the summer evening meetings of the London Chemical Society, held in the hottest and worst ventilated meeting-room it was ever my ill luck to enter.

The heat here during the last week has been positively frightful, and forms the only subject of conversation everywhere.

On some of the Strains of Ships. By W. J. Macquorn Rankine, C.E., LL.D., F.R.S.

From the Lond. Civ. Eng. and Arch. Journal, Oct., 1864.

Read before the British Association.

In previous scientific investigations respecting the strains which ships have to bear, it has been usual to suppose the ship balanced on a point of rock, or supported at the ends on two rocks. The strains which would thus be produced are far more severe than any which have to be born by a ship afloat. The author computes the most severe straining action which can act on a ship afloat—viz: that which takes place when she is supported amidships on a wave-crest, and dry at the ends; and he finds that the bending action cannot exceed that due to the weight of the ship with a leverage of one-twentieth of her length, and that the racking action cannot exceed about $\frac{16}{100}$ths of her weight. Applying those results to two remarkably good examples of ships of 2680 tons displacement, one of iron and the other of wood, described by Mr. John Vernon in a paper read to the Institution of Mechanical Engineers, in 1863, he finds the following values of the greatest stress of different kinds exerted on the material of the ship:—

In the iron ship, tension	3·98	tons per	square inch.
" " thrust	2·35	"	"
" " racking stress	0·975	"	"

It follows that in the iron ship the factor of safety against bending is between 5 and 6, agreeing exactly with the best practice of engineers; and that there is a great surplus of strength against racking.

In the wooden ship, tension 0·375 ton per square inch.
" " thrust 0·293 " "

Here the factor of safety is between 10 and 15, which is also agreeable to good practice in carpentry. As for the racking action, the iron diagonal braces required by Lloyd's rules would be sufficient to bear one-third of it only, leaving the rest to be borne by the friction and adhesion at the seams of the planking.

Consumption of Water.

From the London Artizan, Sept., 1864.

A man is generally supposed to require about ½ gallon of water per day for drinking, cooking, &c., and about 4 gallons more for washing, bathing, and other purposes; a family of 5 heads will require about 9 gallons per day. In Paris, the consumption of this liquid is officially stated to be

4½	gallons	for	every man	per day.
16½	"	"	horse	"
9	"	for a two-wheeled carriage		per day.
16½	"	four	"	" "
92	"	for every square yard of garden		per annum.
66	"	for a bath		per day.
⅛	"	for every square yard of public road		per day.

The consumption in Madrid, according to the report of the directors of the Canal de Isabella II. Company, is

5¾	gallons	for	every man	per diem.
21½	"	"	horse	"
14½	"	"	two-wheeled carriage	per diem.
21½	"	"	four	" "
12	"	"	square yard of garden	"

The following is the consumption in gallons, of water, per day and individual, in the chief towns of Europe and America:—Rome, 243; New York, 125; Marseilles, 103½; Besancon, 54; Dijon, 44; Bordeaux, 37½; Hamburg, 28; Genoa, 26½; Madrid, 26; Glasgow, 25; London, 24; Cette, 23; Lyons, 19; Manchester, 18½; Brussels, 17½; Monaco, 17; Toulouse, 16½; Geneva, 16¼; Narbonne, 16; Philadelphia, 15½; Paris, 15; Grenoble, 14½; Montpelier, 13; Nantes, 13; Voiron, 12; Clermont, 12; Edinburgh, 11; Havre 10; Angouleme, 9; Liverpool, 6; Metz, 5½; St. Etienne, 5½; Altona 5½; Constantinople, 4½; Rio de Janeiro, 2. This statement only comprises the quantities of water supplied by aqueducts; those yielded by wells and other means are not easy to ascertain.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, October 20th, 1864.

William Sellers, President, in the chair.

Washington Jones, Recording Secretary.

The minutes of the last meeting were read and approved.

The Board of Managers and Standing Committees reported their minutes.

The Special Committees on Weights, Measures, and Coins, of the United States, and on a uniform system of Screw-threads and Bolt-heads, reported progress.

The following letter, accompanied by a box of shells, from Rear Admiral Dahlgren was read, and referred to the committee on Science and the Arts.

FLAG SHIP PHILADELPHIA.

Charleston Roads, Sept. 12, 1864.

Franklin Institute, Philadelphia.

I transmit herewith the shells of some oysters just removed from the bottoms of iron clads in this squadron. They are the largest found there and are the growth of about six months; the whole bottom is entirely covered with oysters and grass to the great loss of speed which is thus reduced to some three knots the hour, and the rapid growth renders continued efforts necessary for its removal. There is reason to believe that zinc paint will prevent the formation of the oyster, but not of grass or barnacle. Still the removal of even these, detaches the paint also, more or less, and this opens the way for the oyster.

There is no obstacle so great as this, to the use of iron vessels, and I transmit these specimens, in the hope that the Institute may consider the subject worthy of its attention.

Very Respectfully,

J. A. DAHLGREN, *Rear Admiral.*

Donations to the Library were received from the Society of Arts, London; Matthew B. Jackson, Esq., Sheffield, England; the Natural History Society of Montreal; and the Literary and Historical Society of Quebec, Canada; the American Institute of the city of New York, and the Managers of the State Lunatic Asylum Utica, New York; the Smithsonian Institution, and Frederick Emmerick, Washington, D. C.; and Prof. John F. Frazer, Philadelphia.

Mr. Nystrom made the following remarks on Dynamics:

It is my desire this evening to raise a discussion among the members of the Institute, on a subject which does not seem to be very generally understood, namely, on *Force*, *Power*, and *Vis-Viva*.

I have written an article on this subject for the *Journal of the Franklin Institute*, which article has been examined and rejected for publication by Professor Frazer. I have been told by the Actuary

of the Institute that Professor Frazer says "there are so many errors in the article that it is not fit for publication."

About three weeks ago I had an interview with Professor Frazer, discussed with him the subject, and found his opinion to differ considerably from my own views, as well as from the general received opinion among philosophers of the present day.

I understood Professor Frazer to say that my "definition of force was wrong," and that "force is what I have defined as power," or "pressure multiplied by velocity."

I also understood Professor Frazer to defend Professor Tyndal's theory that heat is motion; he says that I am wrong in my remark on the same, and that I do not understand Professor Tyndal.

I have examined a great many works on the subject, but have not yet been able to find one which treats it clearly.

Moseley's work on Engineering, which is studied at the Military Academy, West Point, is very confused: it has one article on *Work*, one on *Moment of Inertia*, and one on *Vis-Viva*, all without examples or application. It is cruel to burthen a student with such mysteries as that book contain.

Foot-pounds of work and foot-pounds of power are often confounded with each other. In a late edition of Adcock's Pocket Book, a definition is given of units of work, after which the capability of a man working eight hours per day, is given in units of work, said to be copied from M. Morin, but the fact is that Morin's data are foot-pounds of *power* which Mr. Adcock has misrepresented by giving the capability of a man to be some 4000 foot-pounds of work per day, which is about two tons lifted only one foot in a day's work.

A man loading pig iron into a cart, lifts each pig about five feet high, and may walk a short distance with it, can load some fifty tons in a day's work, which is equivalant to at least 600,000 foot-pounds of work, instead of 4000, as given by Mr. Adcock.

The power of an ordinary man is about 50 pounds raised one foot per second, which will amount to between one and two millions of foot-pounds of work in a day.

One pound raised one foot is called one unit of work, by which the labor a man is capable to perform in a day, will be represented by millions. This unit of work is about the right size for a tumble-bug, for two millions of tumble-bugs can do about the same amount of labor as one man in a unit of time. That my comparison is not absurd I may mention that the ball which the tumble-bug rolls, weighs about a quarter of an ounce in this part of the country; but further South and in Asia, I have seen them as heavy as one ounce: two millions of those balls will weigh some 25 tons, lifted over the unevenness of the ground, I would roughly estimate to some 20 to 30 feet in one day, the work of which will be some 1500000 foot-pounds, or the same as that of a man.

You see the absurdity of applying such unit of work in practice, and the result is, that it is lost sight of, and used only by Professors in Colleges, and in school-books.

Here Mr. Nystrom was requested to give a definition of force, and explain the difference between *Force*, *Power*, and *Work*, to which he replied, I am yet not able to give a philosophical definition of force, and believe that that cannot be done until the physical constitution of heat, electricity and magnetism is revealed, but I have given in the article on Physical Work, a practical definition of force, which will hold good after a true philosophical definition is given.

The whole science of Dynamics, is contained in the following simple expressions.

Elements.		*Functions.*
Force	$= F$	Power $P = FV$.
Velocity	$= V$	Space $S = VT$.
Time	$= T$	Work $W = FVT$.

This includes also all cases of dynamics by the force of gravity, circular motion, and the whole confusion of *energy*, *moment of inertia*, *vis-viva*, &c. There are no more names necessary than the above six, namely, for the three elements and three functions. It will, however, be well to maintain the dynamical terms applied to moving masses, although they in reality mean the same as the above terms.

Mechanical terms.		*Terms for a moving mass.*		
Force,	.	F.	.	Inertia.
Power,	.	$P = FV$.	.	Moment of Inertia,
Work,	.	$W = FVT$.	.	Energy.

The last term should be employed only for the change of motion of a moving mass.

F means the weight of a moving mass, which is denoted by M, in the articles on physical work.

The time $T = \frac{V}{g}$, from the law of gravitation,

and Work $W = \frac{MV^2}{g}$, energy.

In this formula it is supposed that the weight of the moving body is equal to its mass, which will hold good at the surface of the earth, where the acceleratrix $g = 32{,}166$.

The difference between weight and mass, is explained in the article on Work.

Force is recognised by the following terms:—Pressure, action, reaction, attraction, repulsion, compression, tendency, efforts, resistance, gravity, inertia, exertion, cohesion, electricity, magnetism, strain, stress, strength, thrust, burthen, load, squeeze, pull, push; all measured by weight. Force has also been improperly denominated, power, work, energy, throw, cast, heave, &c., &c.

Power is recognised by the following terms:—Dynamic momentum, moment of inertia, impetus, dynamic effect, momentum, traction, pro-

pulsion, impulsion, intensity; all measured by foot-pounds of power. Power has been improperly denominated, force, energy, work, quantity of motion, motion, inertia, strength.

Work is recognised by the following terms:—Energy, vis-viva, labor, throw, cast, haul, drag, draw, occupation, exercise, toiling, lift, raise, heave, cultivate, to tilt; all measured by foot-pounds of work. Work has been improperly denominated, momentum of inertia, power, dynamic momentum, mode of motion, moment of activity, dynamic effect, quantity of action, &c., &c.

MOSELEY calls work "moment of inertia," but if inertia is force, moment of inertia must evidently be power. It appears that it would be more proper to call power "*Vis-Viva*," and work "*Moment of Vis-Viva*."

In the estimation of foot-pounds of power I have made a deviation from Watt's rule. The unit 33000 pounds raised one foot per minute, I think is very unnatural. A velocity of only one foot per minute cannot be clearly conceived; it is only 0·2 or $\frac{1}{5}$ of an inch per second: and on the other hand, the weight of 33000 pounds, or about 15 tons is too large, and very few can form a clear conception of its magnitude. A horse cannot lift direct a weight of 15 tons: the ordinary pull of a horse is 200 to 300 pounds, and a horse cart load is about one ton. Therefore it is my humble opinion that the foot-pounds of power ought to be brought nearer the ordinary peformance of a horse, or one pound lifted one foot per second as a foot-pound, which will be 550 foot-pounds per horse power. A velocity of one foot per second is conceivable, and 550 pounds can be lifted direct by a horse. This kind of foot-pounds is used in most parts of Europe. The Swedish horse-power is 600, the German 513 foot-pounds.

Lately there appeared in the *Journal*, a long article of inquiry on the subject of *Force*, *Power*, and *Vis-Viva*, written by Mr. Trautwine, which inquiry has not been answered. Mr. Trautwine is familiar with the leading scientific works of the day, and it is my humble opinion that, if he does not understand them, it is not his fault. We cannot take out of a book what is not in it.

Not long ago there appeared an article in the *Journal*, where foot-pounds were misapplied, which error renders that article worse than useless; for it may set readers of the *Journal* into confusion, and lead them into wrong speculations.

Numerous correspondents are seeking information on the subject through the *Scientific American*, but do not obtain satisfactory answers.

It is not necessary to dwell any longer on points where the subject is misconceived, for it is heretofore nowhere properly explained.

My article on Work is what I consider the subject in its true elementary form. Should like very much to have it criticised, improved, and simplified.